The 11th AOGEOSS Asia Pacific Symposium, Sectional meeting for AOGEOSS TG7

Multi-source data Synergized Quantitative remote sensing production system （MuSyQ）

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Outline

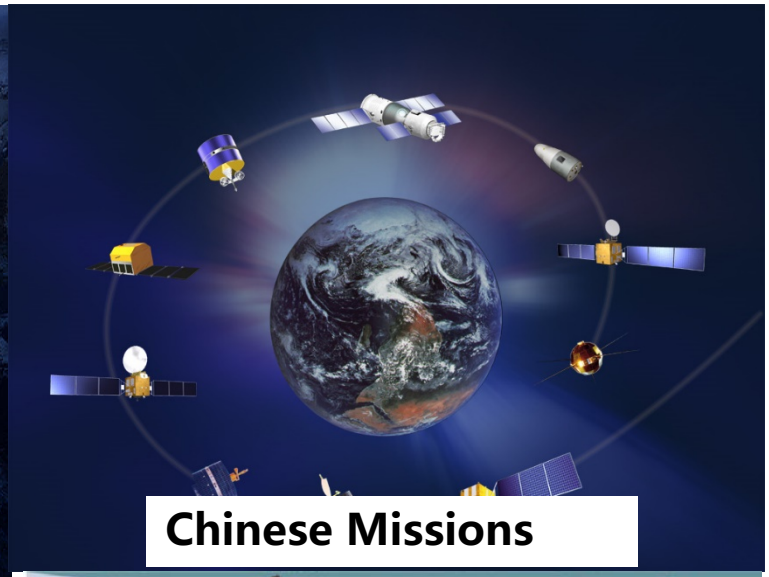
1. Background
2. Objectives
3. Framework
4. Data Normalization
5. MuSyQ Products
6. Hardware
7. Conclusions

1. Background

AOGEOSS TG7, The National High Technology Research and Development Program of China under Grant 2013AA12A301 and 2012AA12A304; *DRAGON 3 ID. 10680*

1.1 The explosive development of remote sensing data

NASA Earth Science_Division Operating Missions



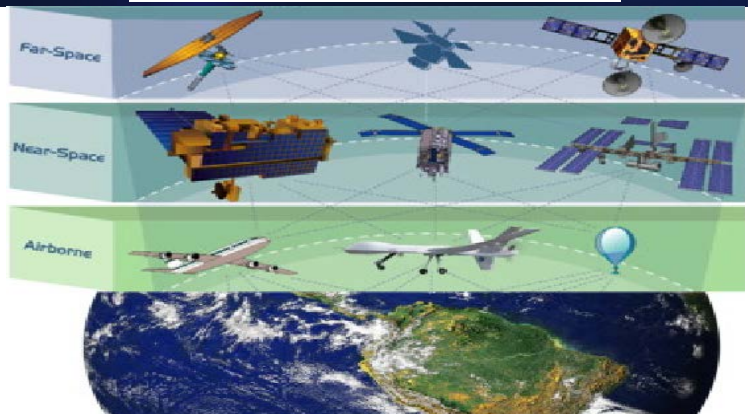
Chinese Missions

Satellites have been over 1000

Data amount in one DC：100**TB**

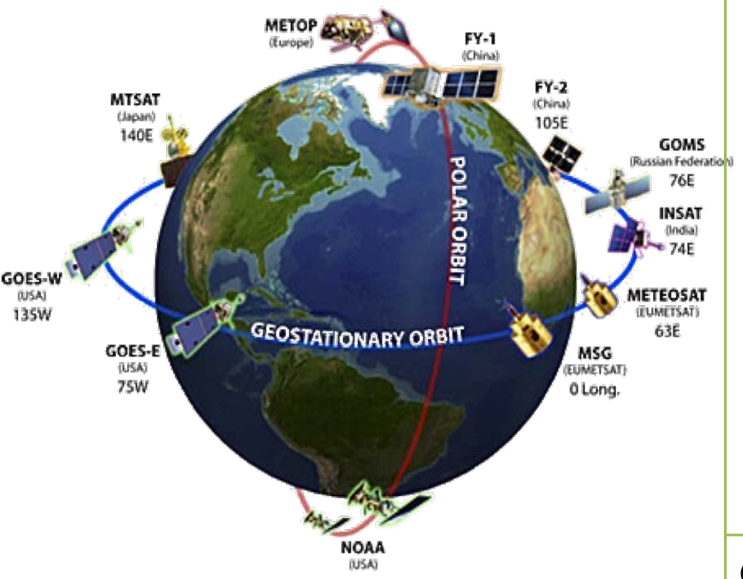
National data center：over **PB**

Global data amount：over **EB**



Ground- airborne-satellite *observations*

So Many RS data

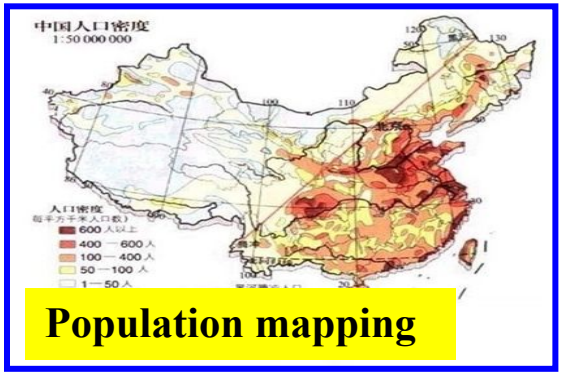


Sensor Type	Orbit	Data Examples	Characteristics
Optical			High SR, Low TR
			Moderate SR, Moderate TR
			Low SR, High TR
Others			Extra Information

Greatly improve the quality of RS Products

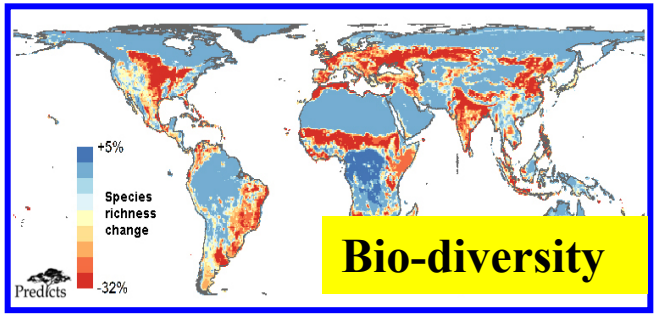
Increasing utilization of RS data

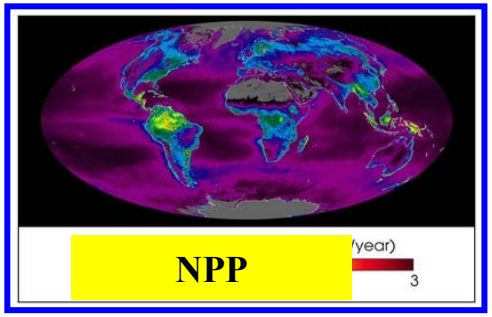
Data to VALUE



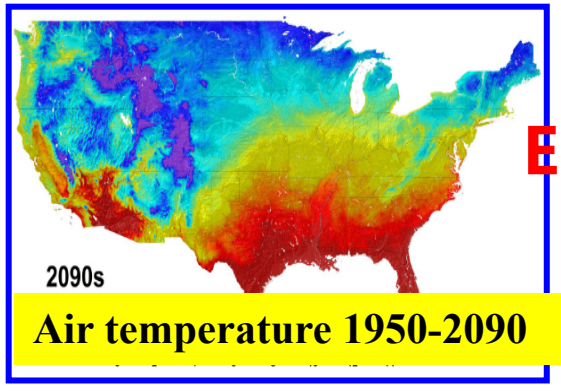
Economy

Guo et al, 2014. Sci. Bulletin of China;
Brown et al., 2000;
Predict Project;
NASA Earth Exchange
NASA:





Ecology



Environment

……

Chinese satellite missions

- **FengYun (FY): meteorology**
- **HaiYang (HY): ocean**
- **Huanjing (HJ): environmental monitoring**
- **ZiYuan (ZY): resource monitoring, surveying and mapping**
- **GaoFen (GF): high spatial resolution observing**
- **Satellites for hydrology and carbon observing**
- **And more**
- **Over 40 satellites in next 5 years**
- **Include visible, infrared, microwave, lidar, hyperspectra, gravity, and everything**

1.2 Requirements of RS products from applications

- Existing land surface remote sensing products
  - MODIS, MERIS, FY3-MERSI/VIRR, AVHRR…
  - From single satellite data
  - Usually not very consistent
  - Temporal resolution usually in 16 days is restricted because of clouds and aerosol
- Requirements from applications
  - Higher temporal resolution RS products are better
  - Consistent of RS products

Chances

- More satellites → more observations
- Wider swath → shorter revisiting period

↓

Monthly observation without clouds are possible

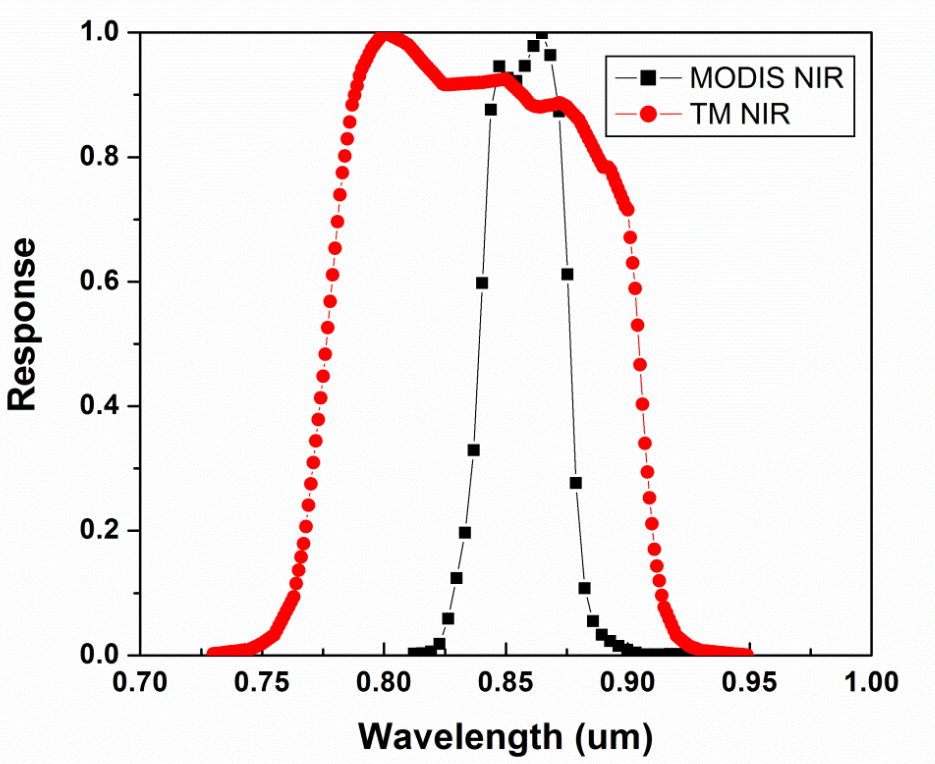
↓

Finer applications on agriculture, environmental mornitoring, land surveying etc.

1.3 What are the problems?

Theoretically, it is easy as long as similar data have:

- The same position
- The same spectra
- The same radiometric capability
- Atmospheric effects free



Spectra Difference

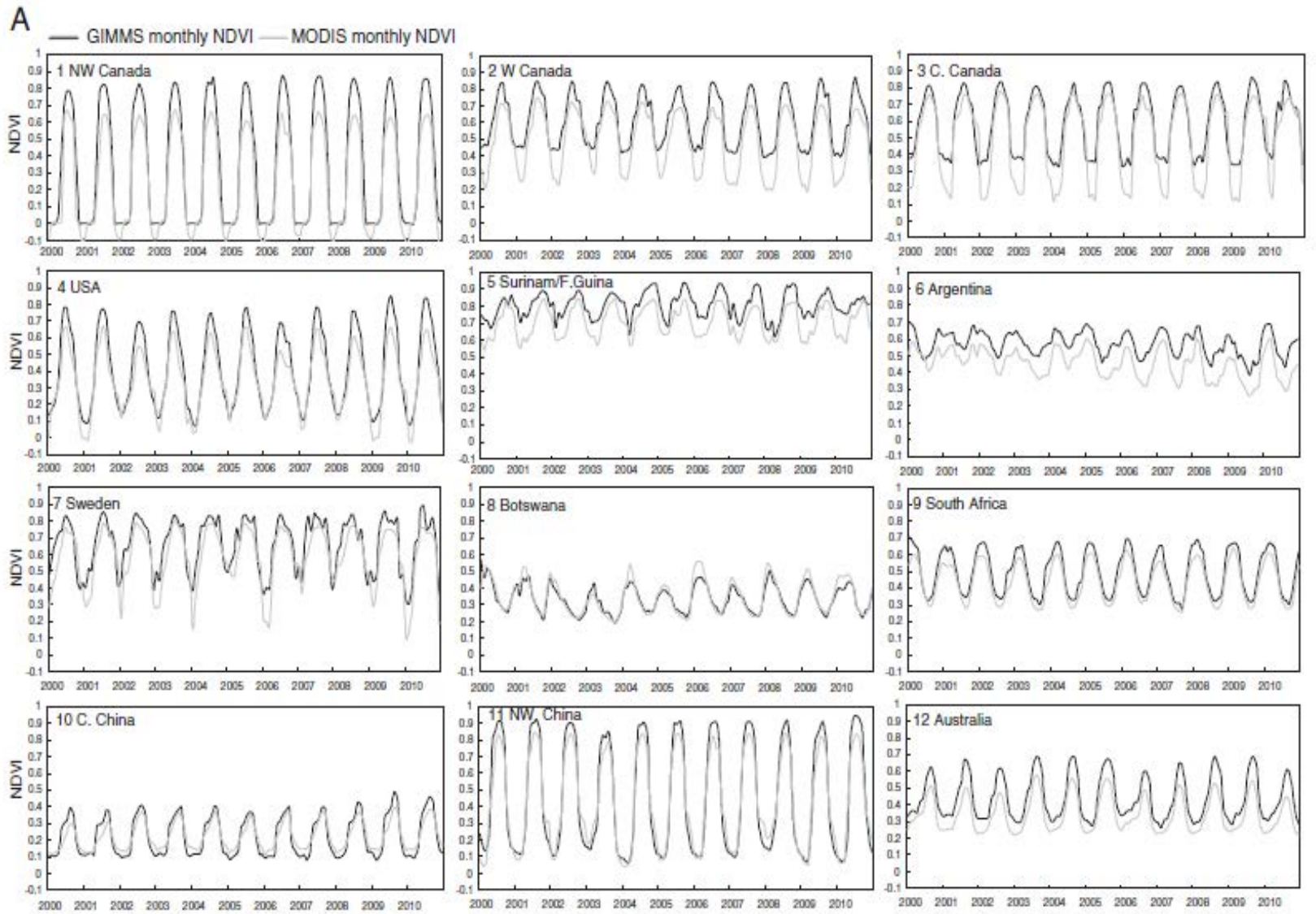
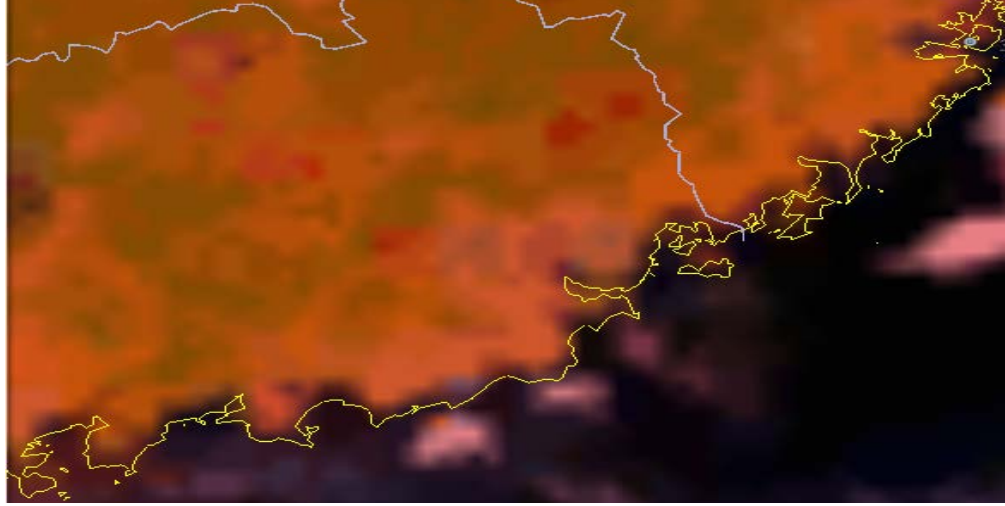


Fig. 6. (A) Time series of monthly GIMMS and MODIS NDVI (2000–2010) for selected regions (Fig. 4G) and (B) the corresponding scatterplots including regression slope, intercept and correlation coefficient. Pixels influenced from snow cover (Fig. 6A1) are excluded in the correlation analysis (Fig. 4) and in the Fig. 6B1 scatterplot.

MODIS-AVHRR NDVI Comparison

Radiometric Difference

FY3A



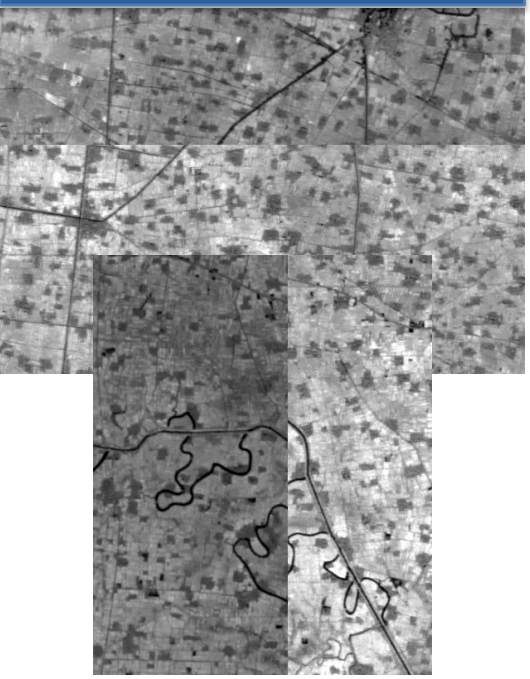
AVHRR

Geometric Difference

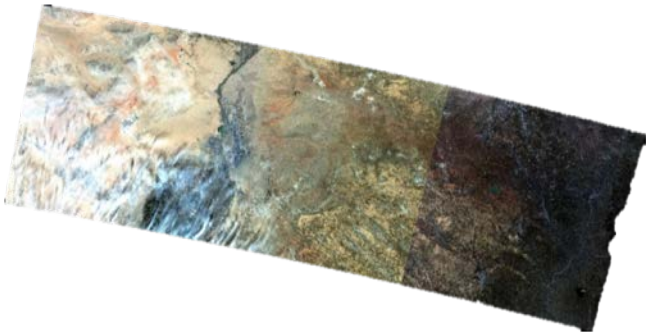
Sat/Sensor	1	2	3	4	5	6	7	8	9	10
N17/AVHRR	5.1	6.9	6.5	5.4	5.5	5.9	5.3	6.3	6.4	6.2
FY3A/VIRR	6.7	3.7	4.6	2.6	4.5	3.8	3.5	3.2	2.7	6.1
FY3A/MERSI	2.7	2.3	1.7	2.2	3.3	3.2	2.4	2.8	3.1	1.9
FY2E/VISSR	12.9	19.3	17.2	13.0	17.9	16.5	17.4	13.5	16.3	18.1
MTSAT2	3.51	4.98	4.24	4.06	5.56	4.56	5.23	4.1	4.3	4.56
MSG2	1.75	1.8	1.67	1.6	1.72	1.6	1.66	1.51	1.43	1.77
GOES	1.56	1.59	1.71	1.53	1.49	1.41	1.5	1.63	1.76	1.68

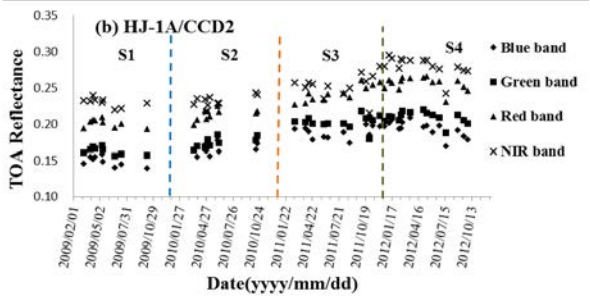
Challenges

Geolocation bias

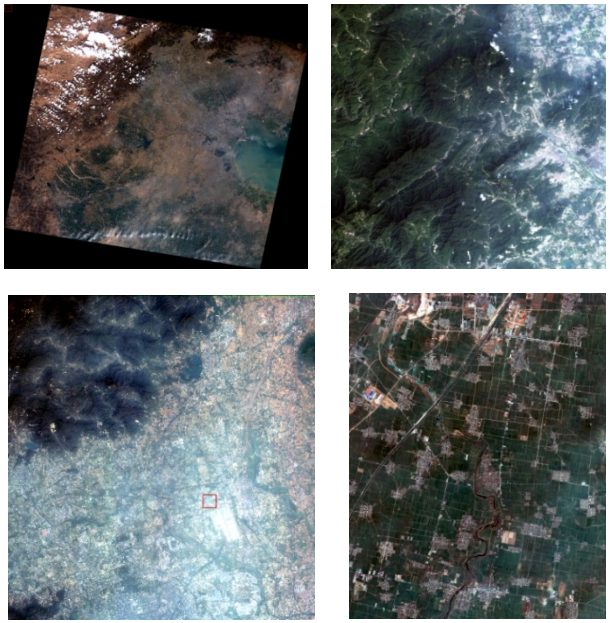


Radiometric bias





Atmospheric effect



2. Objectives

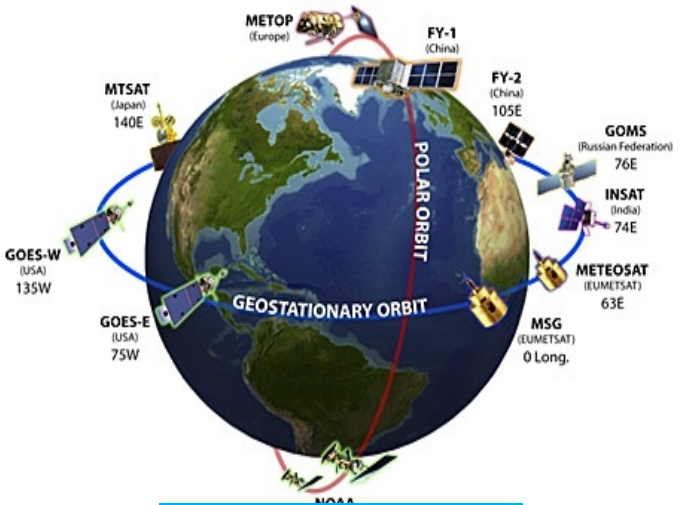
Trend: long-term environmental products leveraging off the advantages of multiple instruments

- Townshend et al. (2002)
  - It is to be hoped that creation of long-term environmental products leveraging off the advantages of multiple instruments will become increasingly common in the future.

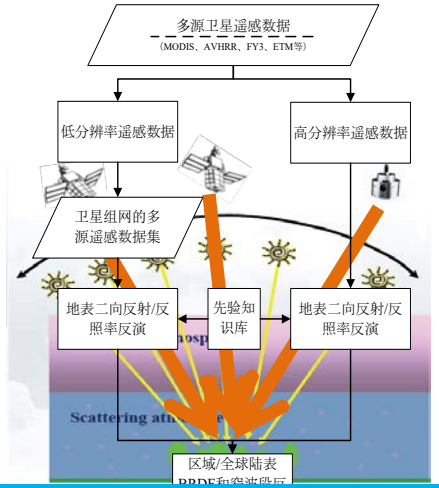
- **Similar data together to improve the temporal frequency**
- **Multi-scale data together to improve the spatial resolution**
- **Multi-source data together to introduce extra information**

3. Framework

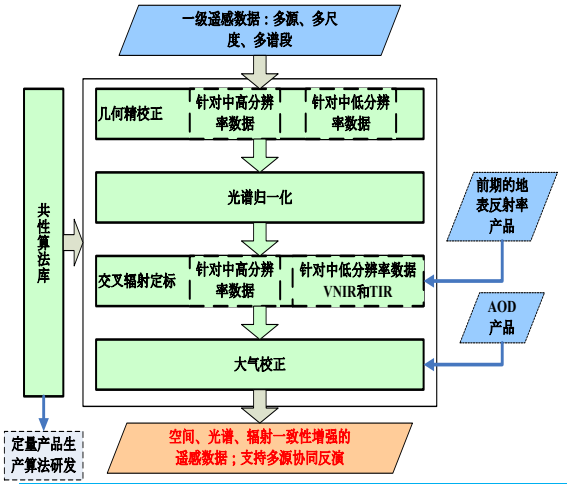
The Framework



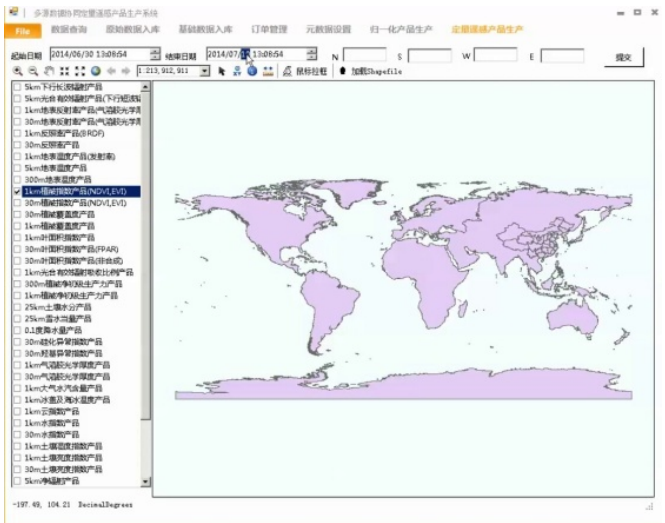
Satellites networking



Parameters retrieving using data from multi-sensors



Data normalization



MuSyQ

Automation

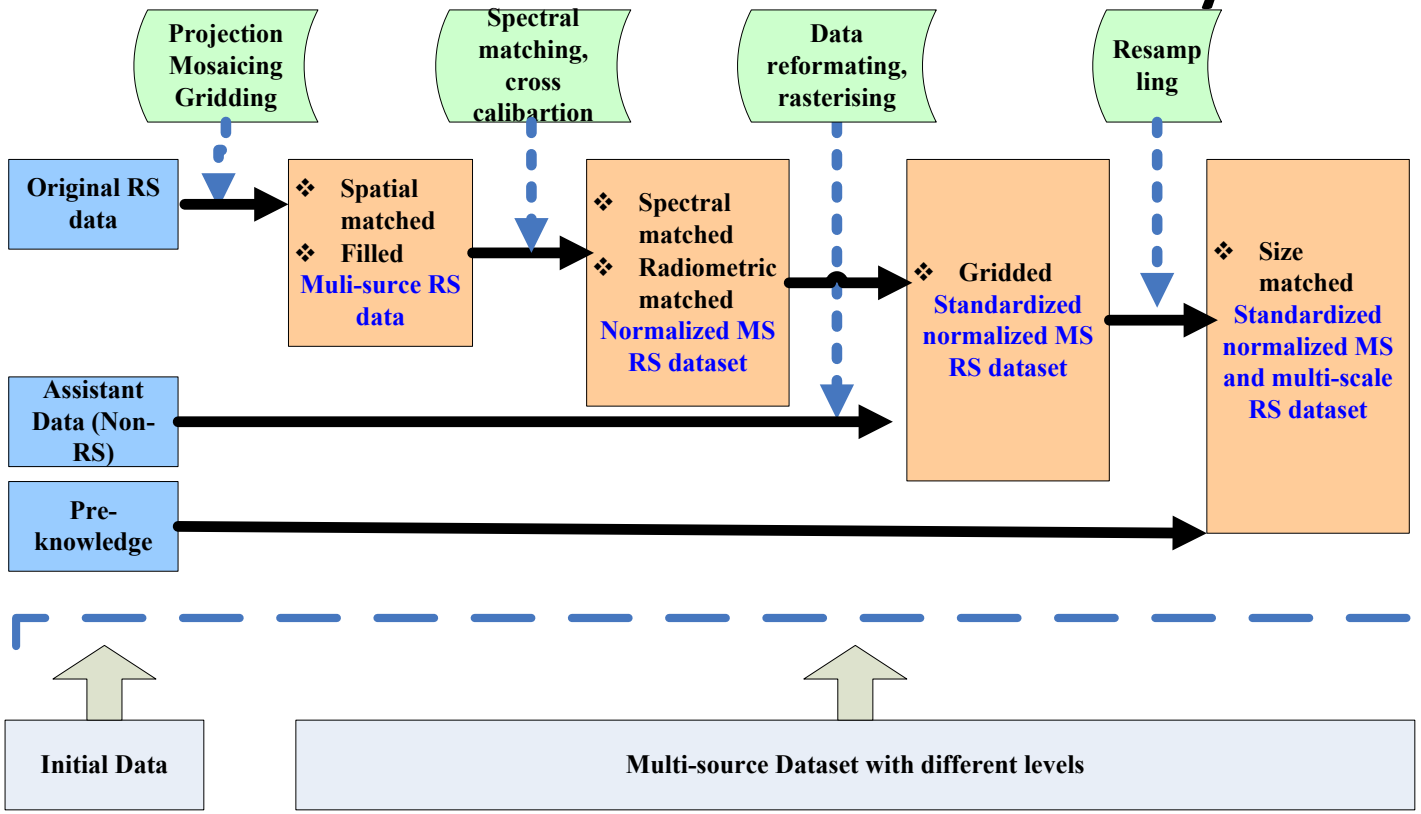
High performance computing

Multi-source and Multi-scale RS Data Normalization Processing System

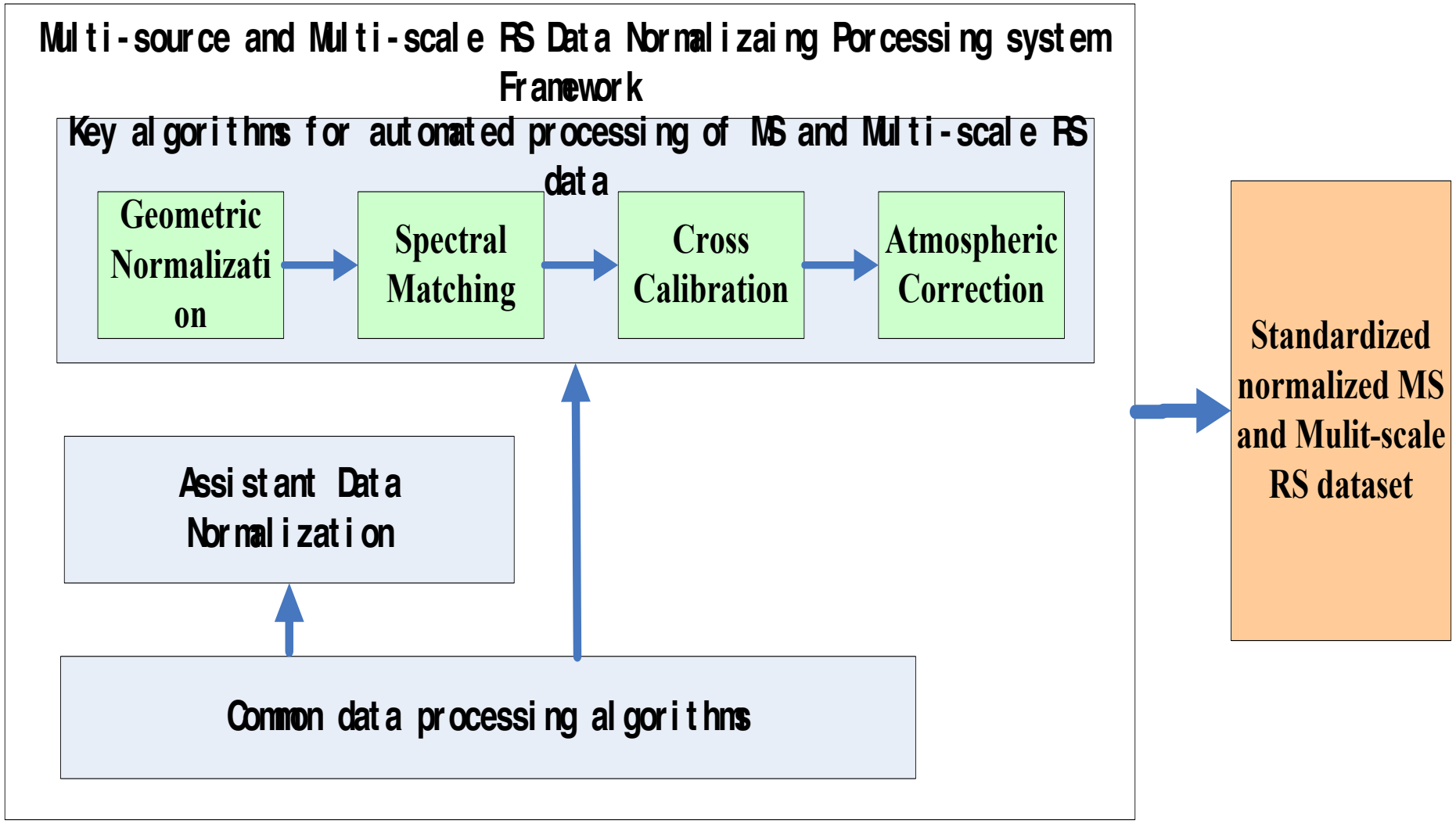
4. Data normalization

Objectives

- Develop algorithms for spectral, geometric, and radiometric normalization
- Generate multi-source RS dataset with very high consistency on spectra, geometry, and radiometry
- Global observation without clouds in 5 days



The Framework for data normalization



General Ideals

- **Choosing high quality data as the base data for normalization**
  - **Polar Moderate to low： EOS-MOIDS, Landsat-TM/ETM+**
  - **Geostationary： EOS-MODIS**
- **Using large amount of knowledgebase to assure the efficiency and the implementability**
  - **MODIS surface reflectance**
  - **DEM**
  - **Land cover dataset**
- **Considering the applicability for data from multi-sensor**

Key algorithms

- **Geometric normalization**
- **Spectral matching**
- **Cross calibration**
- **Atmospheric correction**

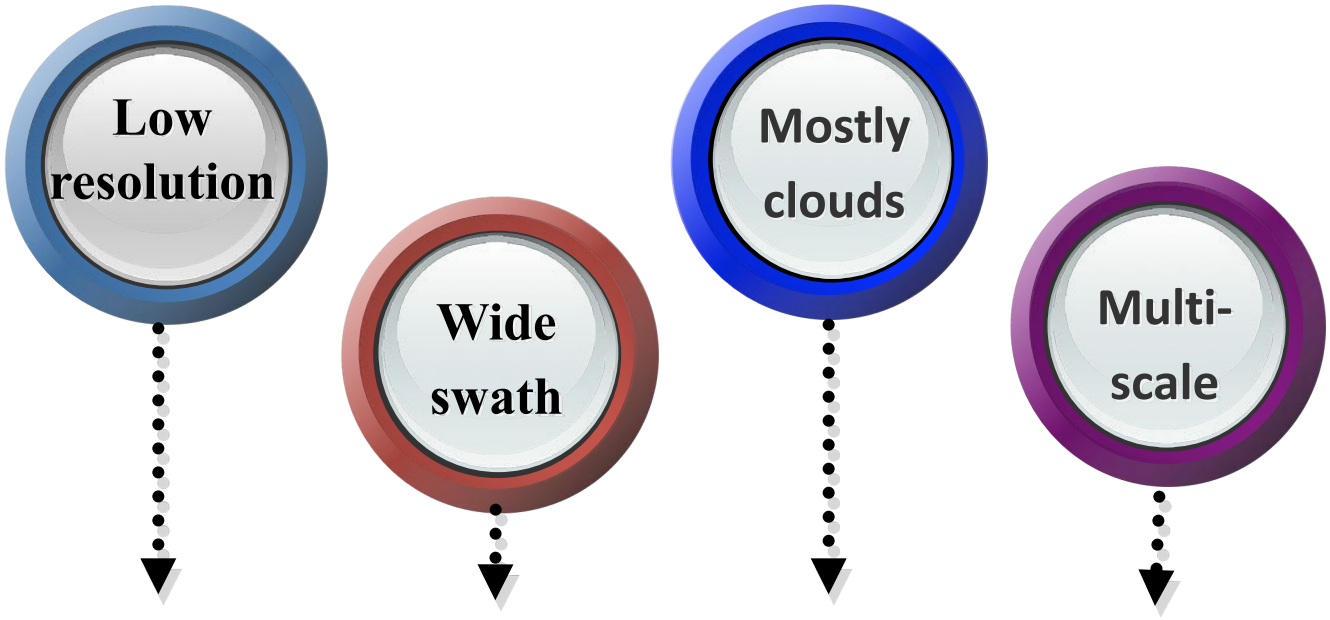
- **Requirements:**
  - For multi-source and multi-scale RS data
  - Automated
  - Highly efficient

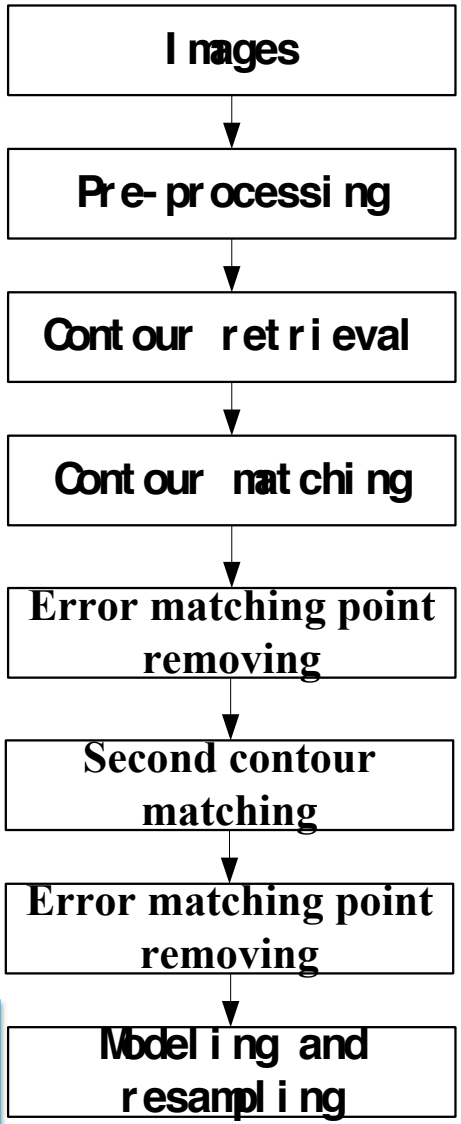
Routinized

Operational

Global

（1）Geometric registration



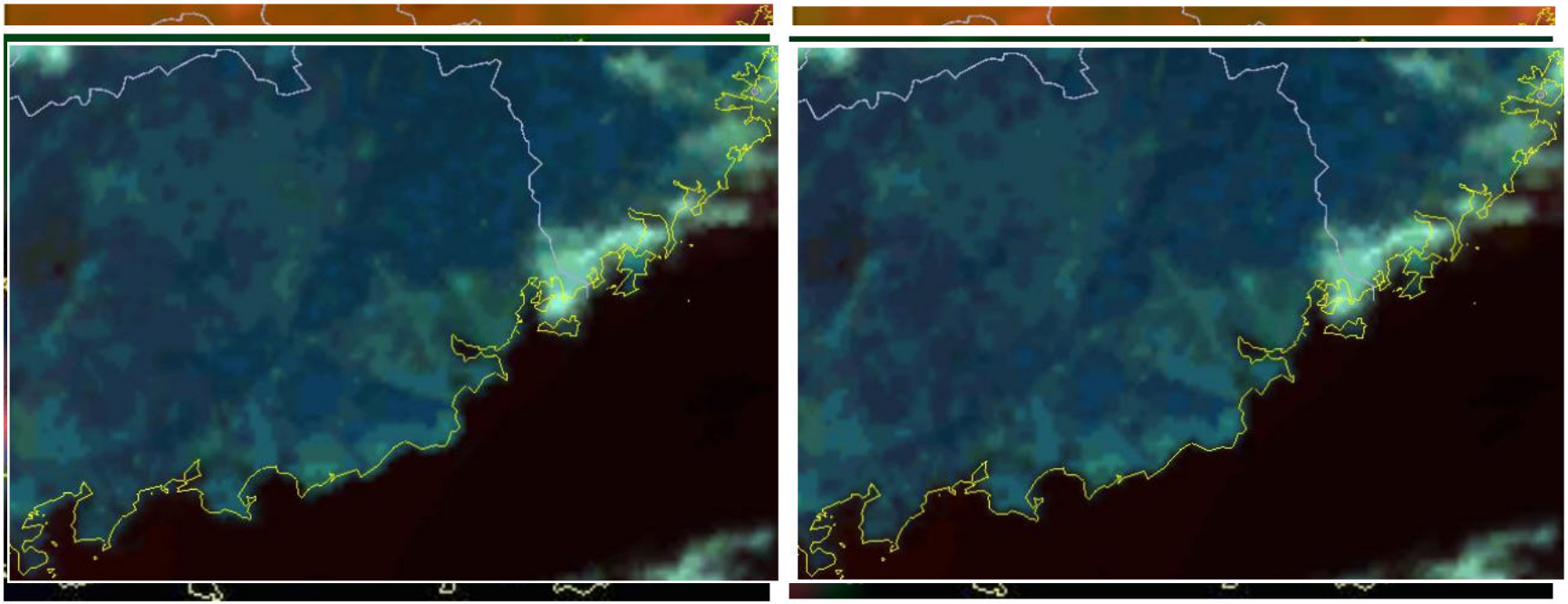


Keys

Use MODIS as base images for image to image registration

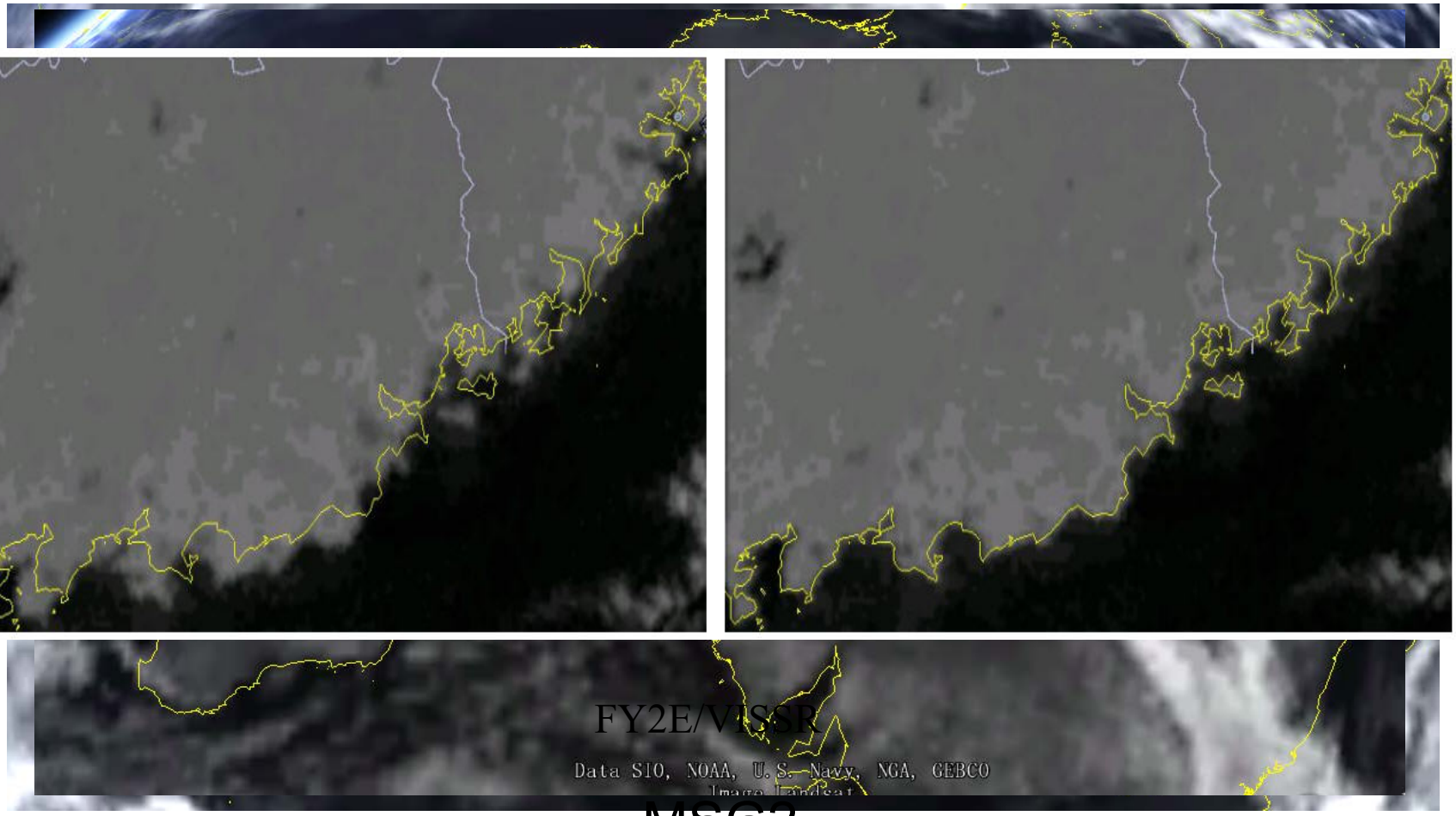
ZHAO et al. MODIS Data-based Spatial Consistency Correction of Low-Resolution Multi-source Remote Sensing Imagery. IGARSS, 2013.

Polar data Results

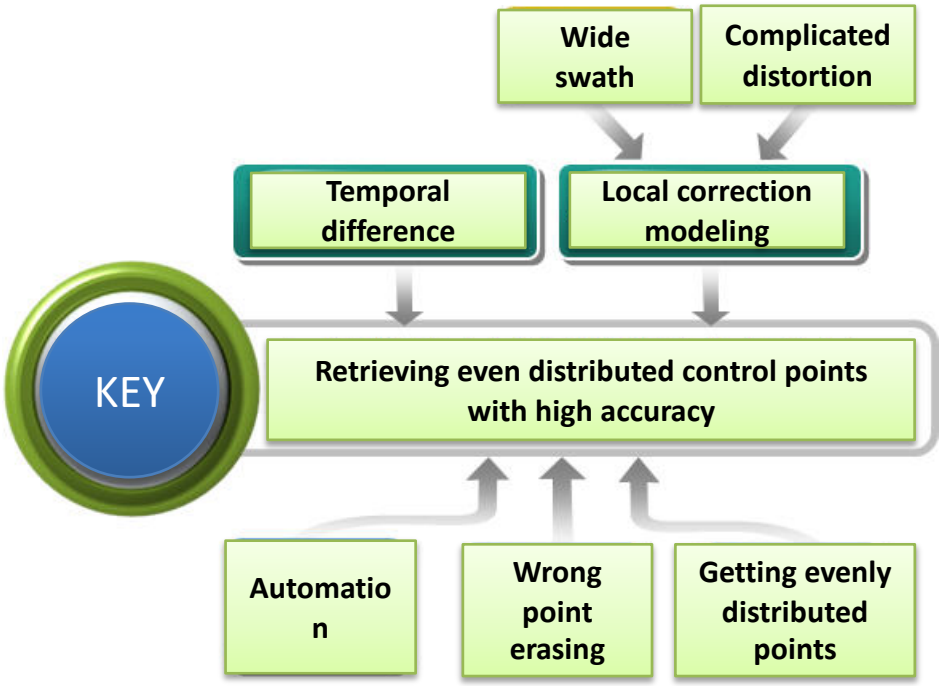


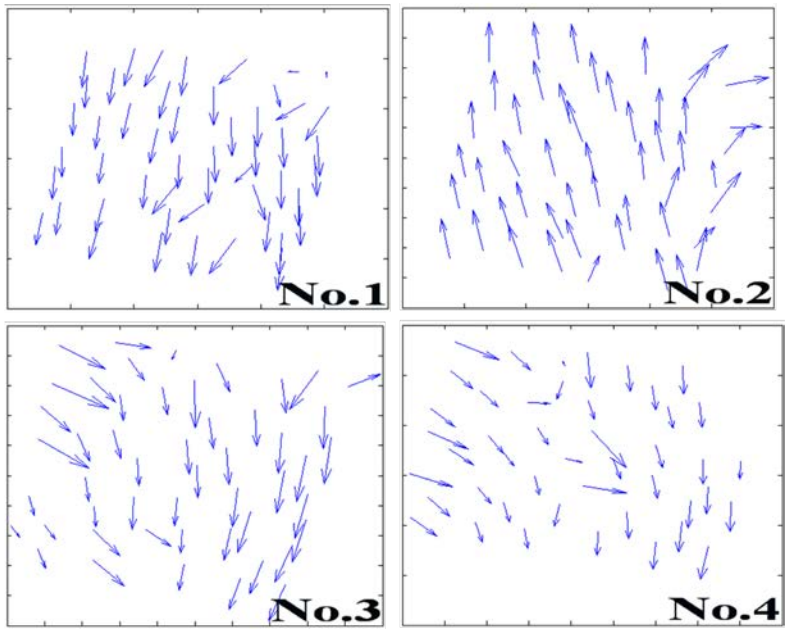
FY3A MERSI FY3A MERSI

Geostationary data results



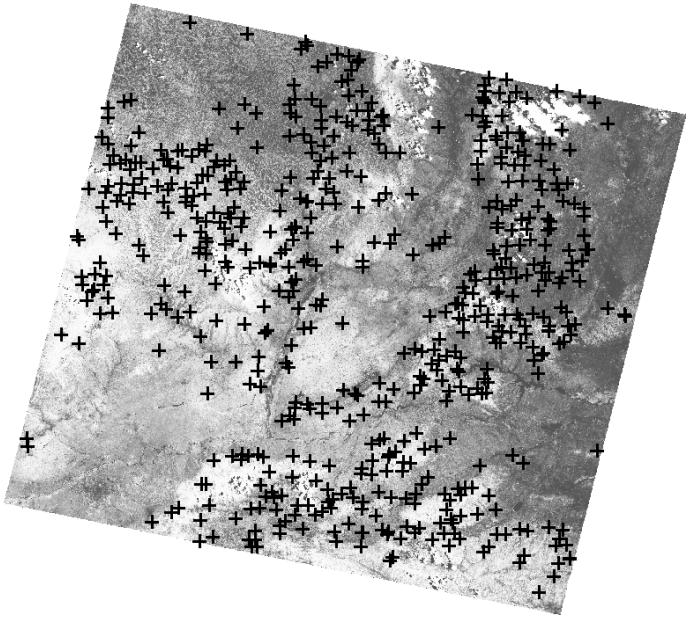
Geometric registration-MH



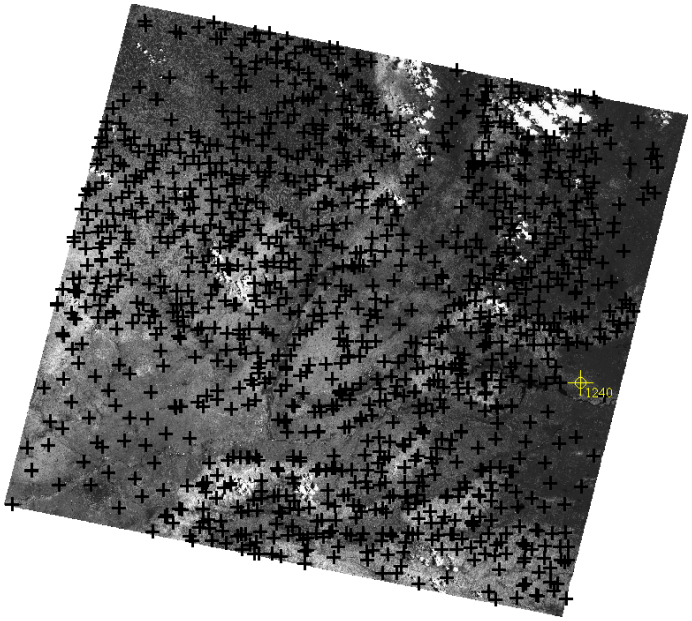


Distortion analysis

The distribution of controlling points

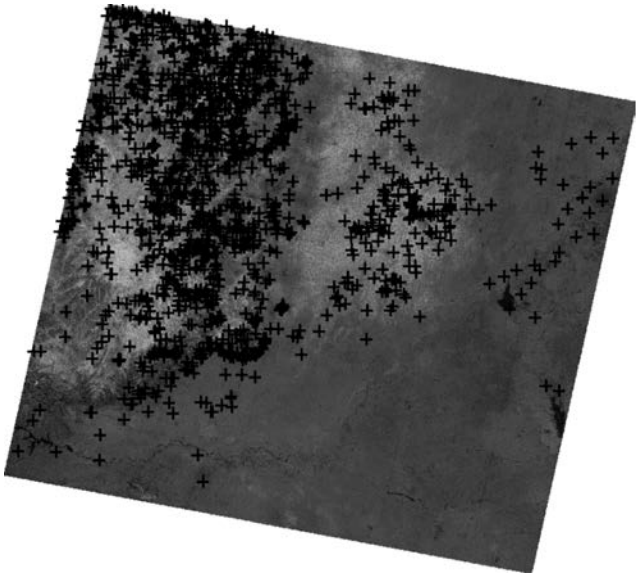


SIFT

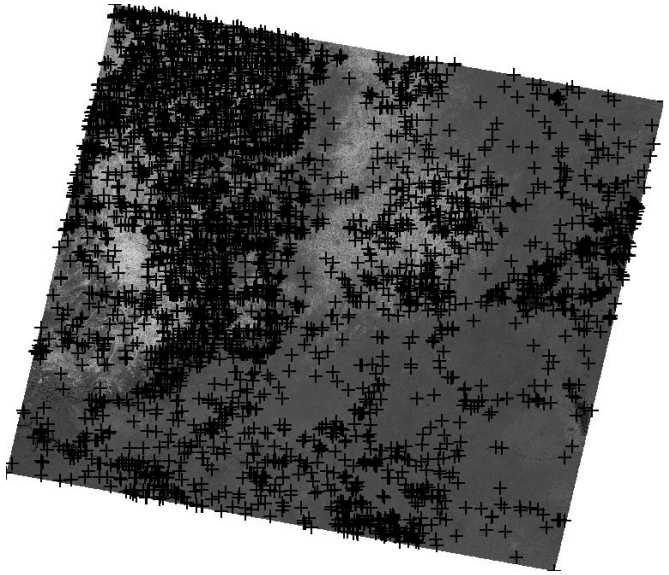


The proposed algorithm

Getting rid of the inaccuracy points

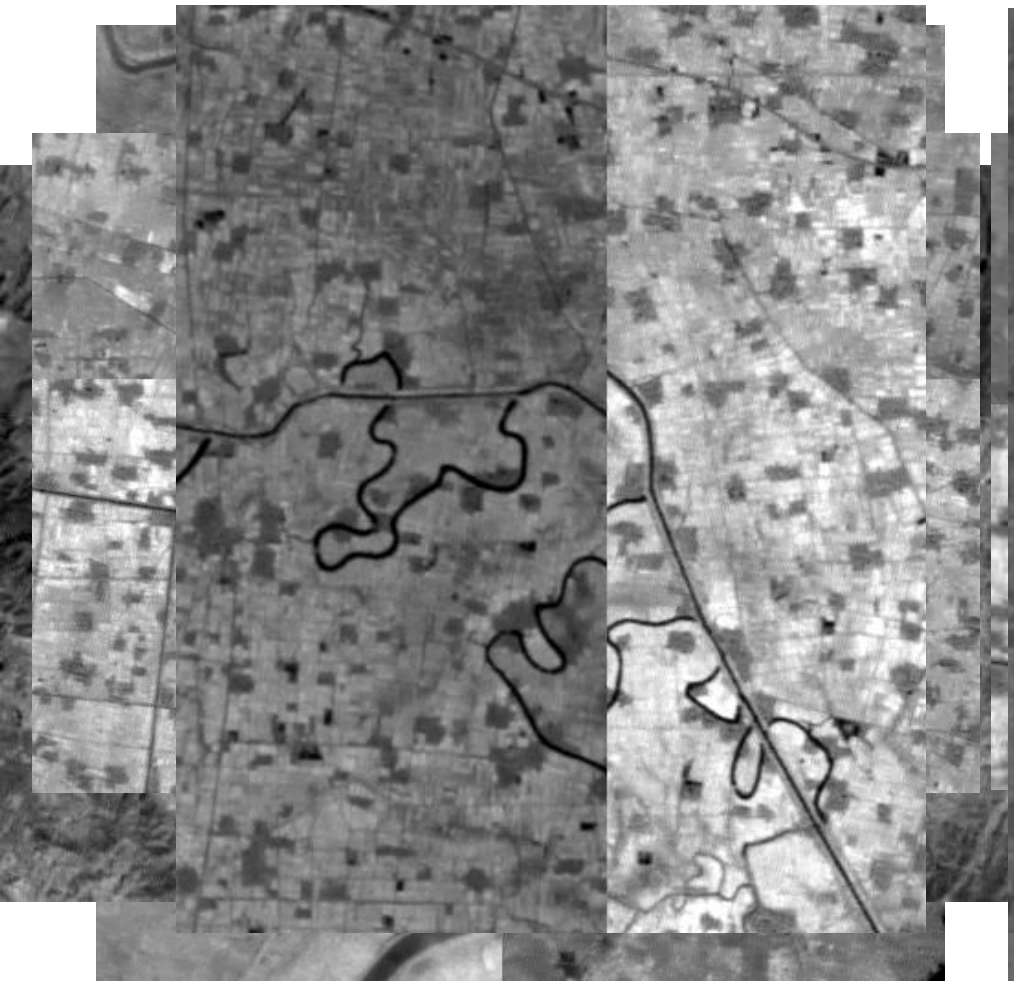


RANSAC

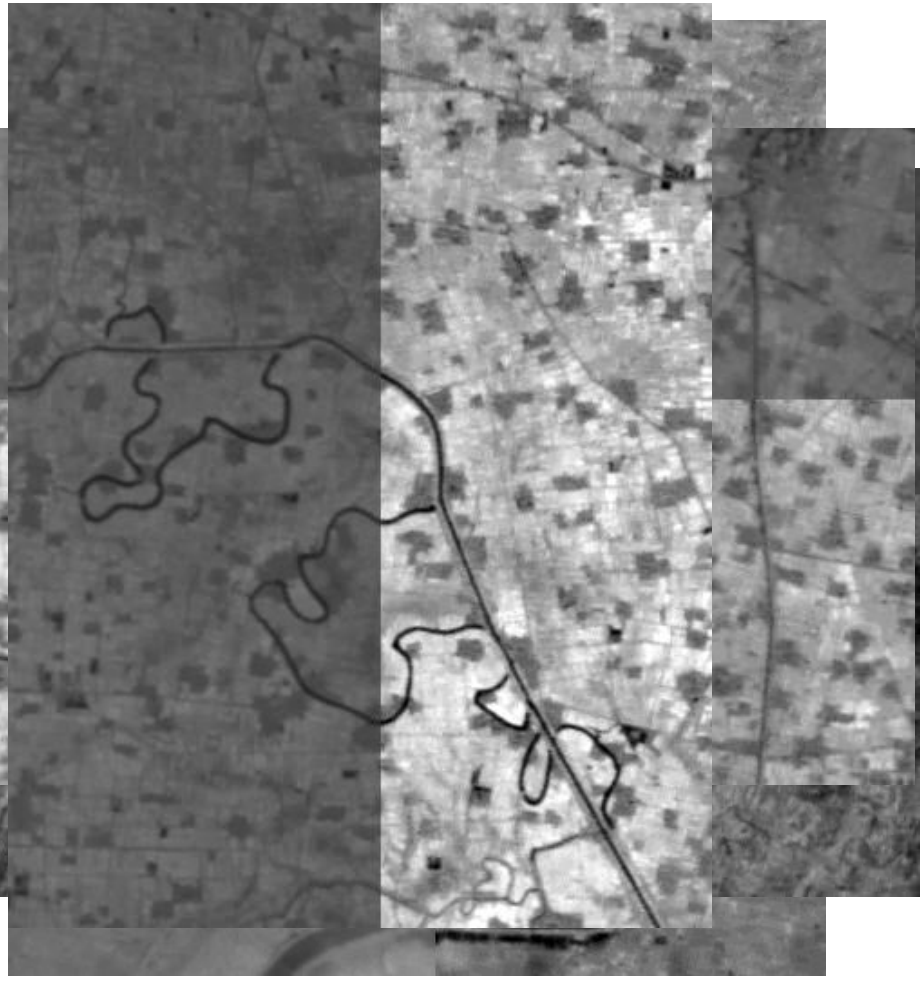


The proposed algorithm

Moderate to high resolution data

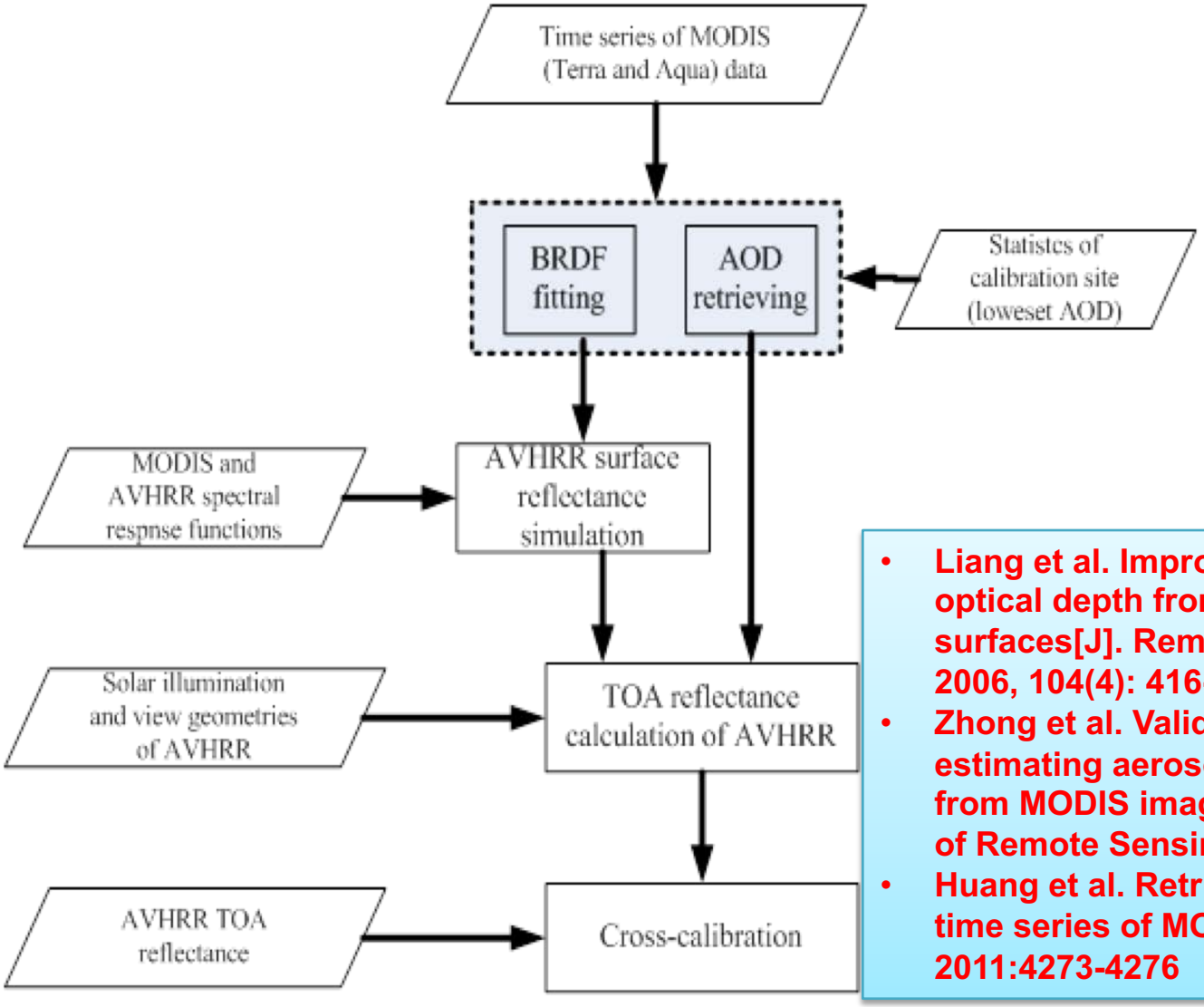


Before correction



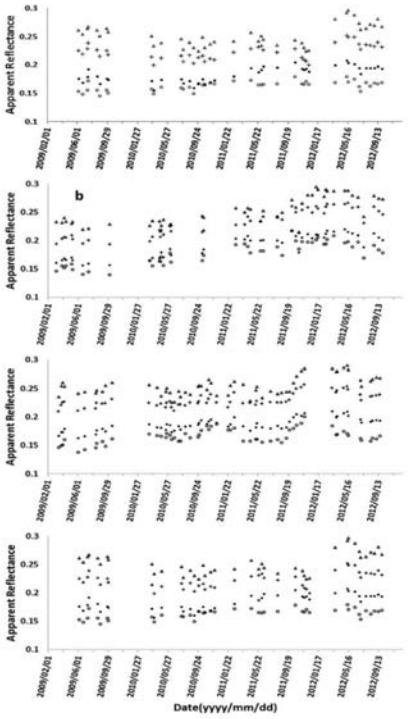
After correction

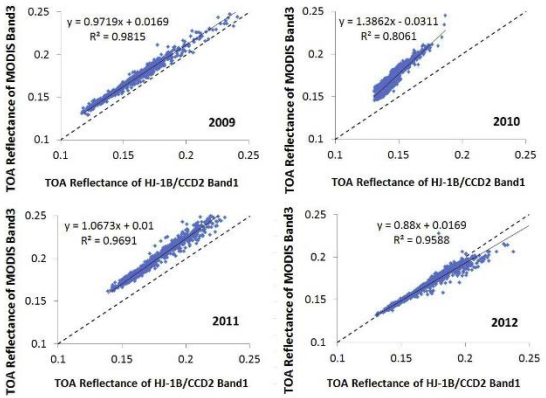
（2）Cross calibration



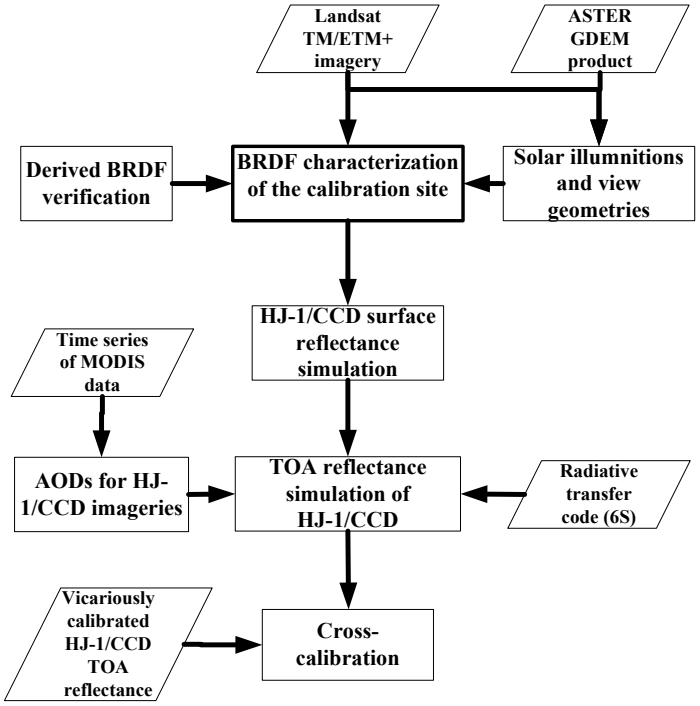
- **Liang et al. Improved estimation of aerosol optical depth from MODIS imagery over land surfaces[J]. Remote Sensing of Environment, 2006, 104(4): 416-425.**
- **Zhong et al. Validating a new algorithm for estimating aerosol optical depths over land from MODIS imagery[J]. International Journal of Remote Sensing, 2007, 28(18): 4207-4214.**
- **Huang et al. Retrieving BRDF Of desert using time series of MODIS imagery IGARSS 2011:4273-4276**

Radiometric cross-calibration-MH





✓ *Zhong B*, Zhang Y, Du T, et al. Cross-Calibration of HJ-1/CCD Over a Desert Site Using Landsat ETM Imagery and ASTER GDEM Product[J]. IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, 2014, 52(11), 7247-7263.



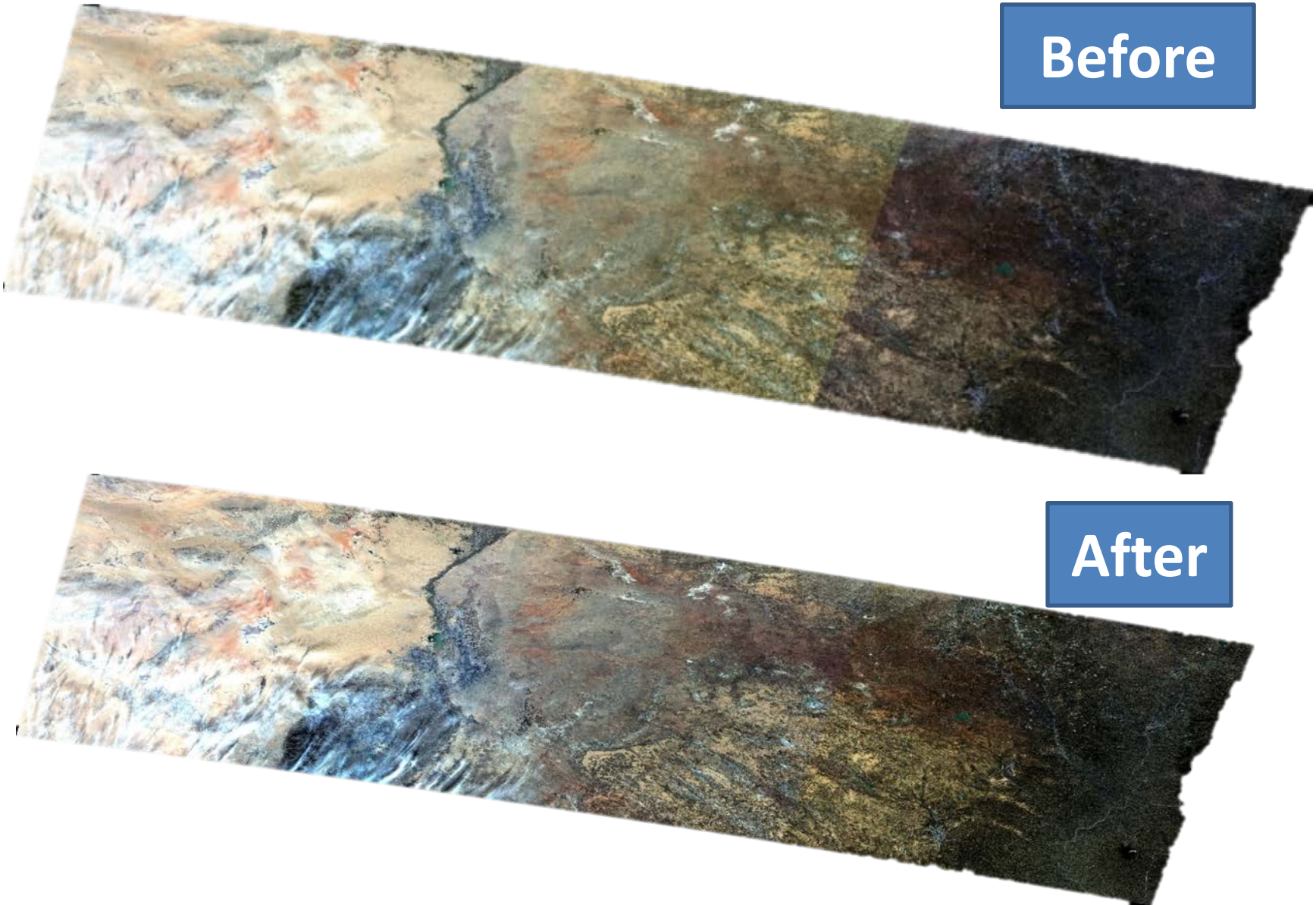
Validation

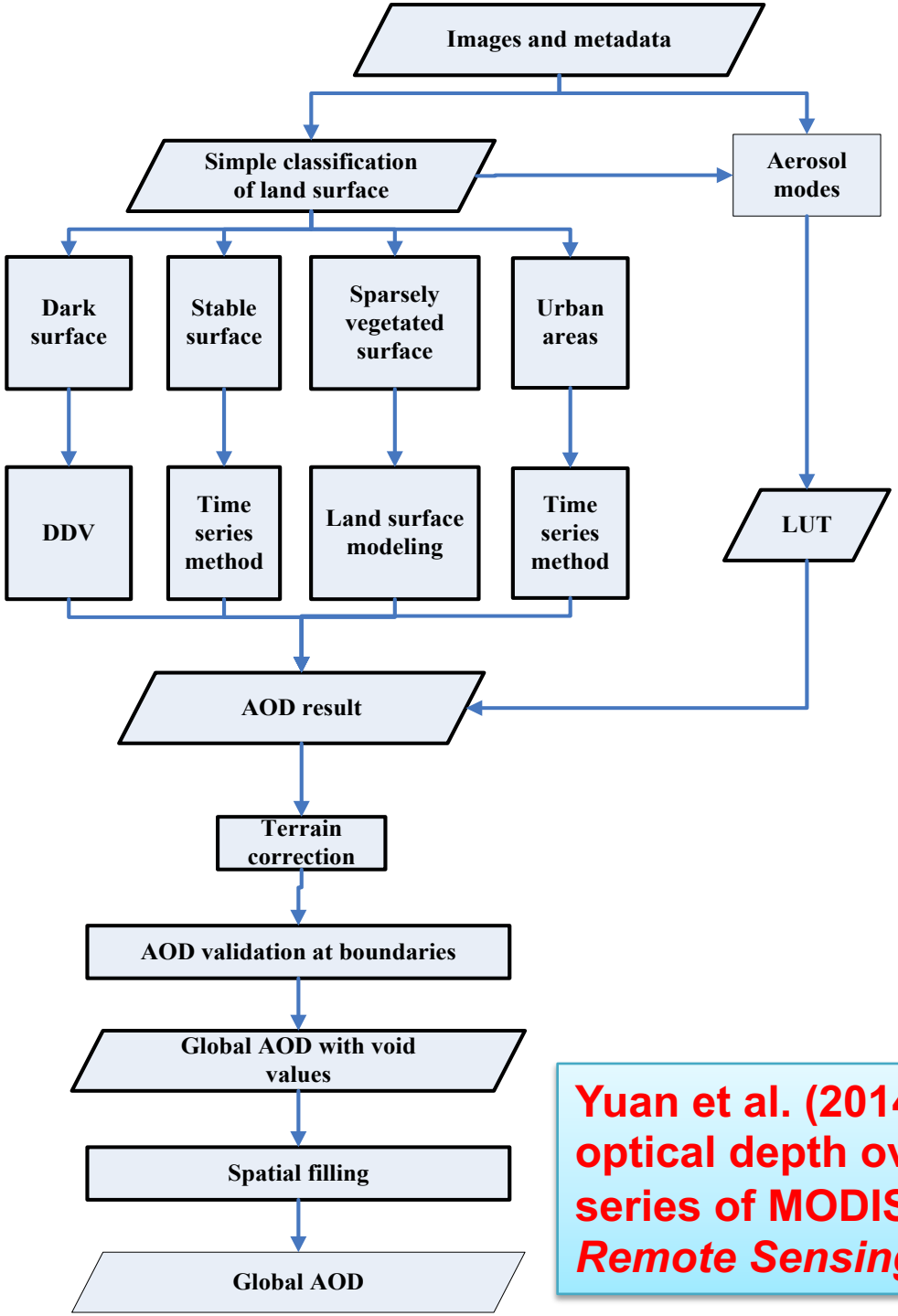
Official calibration over 5%

Date(YYMMDD)	Satellite/ sensor	band	Offset	CCC*	GCC$	TOA radiance by CCC	TOA radiance by GCC	TOA radiance by GM#	Error by CCC	Error by GCC
100811	1A/CCD1	Band1	7.3250	0.8100	0.6925	114.3622	132.5310	108.7449	0.0516	.2187
		Band2	6.0737	0.8155	0.7438	111.3873	121.5427	110.5042	0.0079	.0998
		Band3	3.6123	1.0807	0.9636	97.2444	108.6270	101.1343	0.0384	.0740
		Band4	1.9028	1.0544	1.0545	67.0518	67.04755	70.85944	0.0537	.0537
110928	1B/CCD2	Band1	2.2219	0.8492	0.8352	96.4577	98.03807	96.3980	0.0006	.0170
		Band2	4.0683	0.8761	0.7925	92.1127	101.4051	93.1440	0.0110	.0887
		Band3	5.2537	1.1585	1.1316	87.7656	89.7307	85.3340	0.0284	.0515
		Band4	6.3497	1.0941	1.0578	60.8876	62.7592	59.2300	0.0279	.0596
100812	1A/CCD2	Band1	4.6344	0.9794	0.9230	107.1702	113.4408	110.8736	0.0334	.0231
		Band2	4.0982	0.9016	0.9399	108.1073	103.8745	107.0163	0.0101	.0293
		Band3	3.7360	1.2163	1.3093	100.9593	94.0571	96.05768	0.0510	.0208
		Band4	1.3178	1.2564	0.7385	68.3588	115.3811	66.1060	0.0340	.7453
09025	1B/CCD1	Band1	1.6146	0.4963	0.4817	103.4974	106.5854	105.879	0.0230	.0066
		Band2	6.2193	0.5257	0.4728	102.2621	113.008	105.094	0.0276	.0753
		Band3	6.2193	0.6959	0.6262	96.0534	106.0525	97.1140	0.0110	.0920
		Band4	2.8302	0.7457	0.7007	68.5089	72.7268	66.4500	0.0300	.0944

The proposed method less than 5%

Radiometric cross-calibration



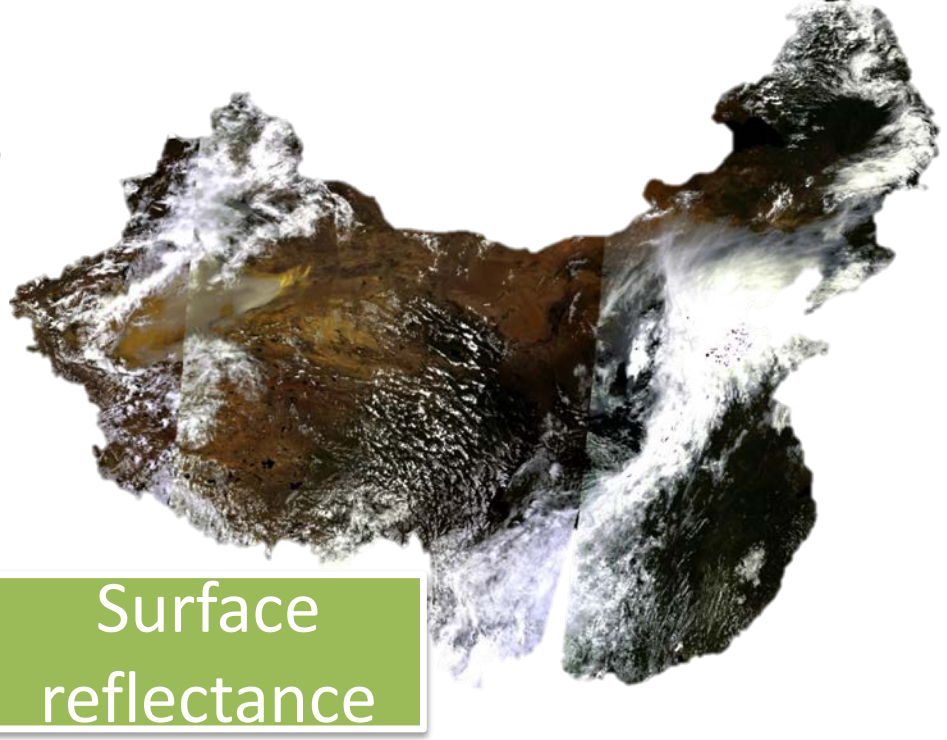


（3）Atmospheric correction

- For general atmospheric conditions
- For general land surfaces, especially for bright surface and sparsely vegetated surface
- For any type of RS data including data without shortwave infrared band
- Gap filled and no void values
- Double checked and validated at boundaries

Yuan et al. (2014, November). Retrieval of aerosol optical depth over bare soil surfaces using time series of MODIS imagery. In *SPIE Asia Pacific Remote Sensing* (pp. 92591Q-92591Q).

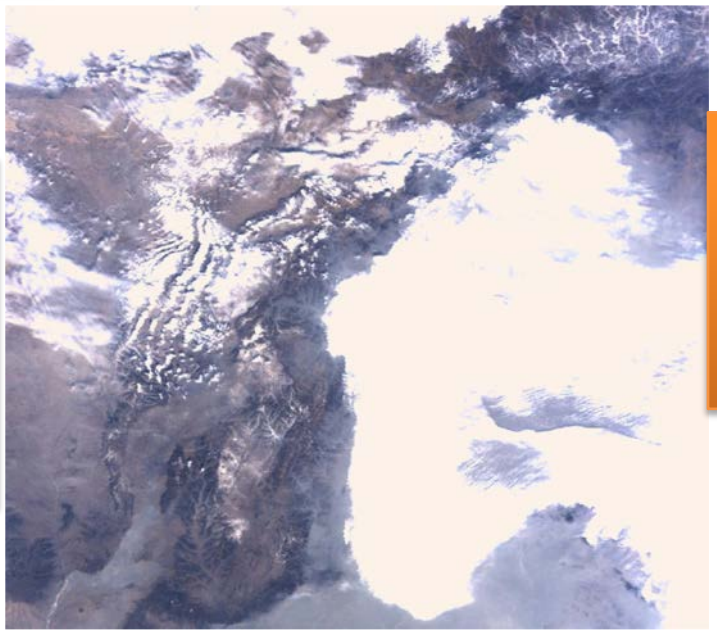
TOA reflectance



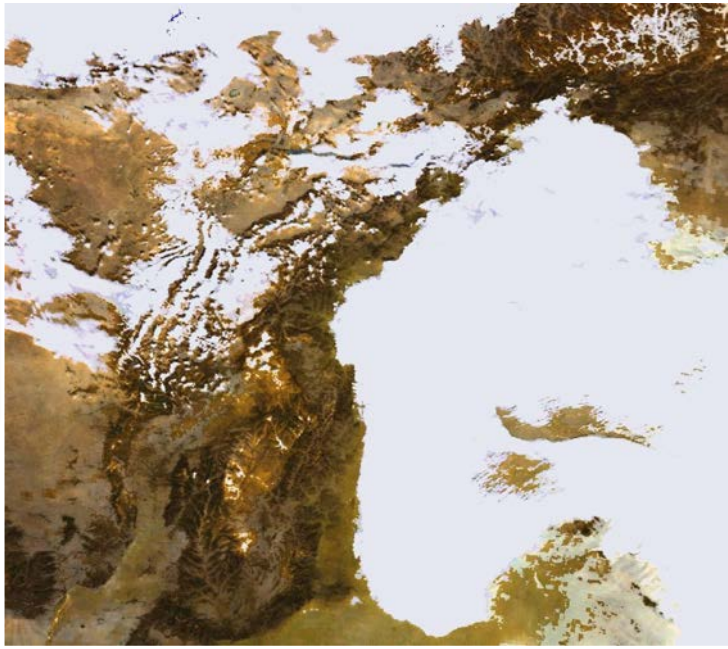
Surface reflectance

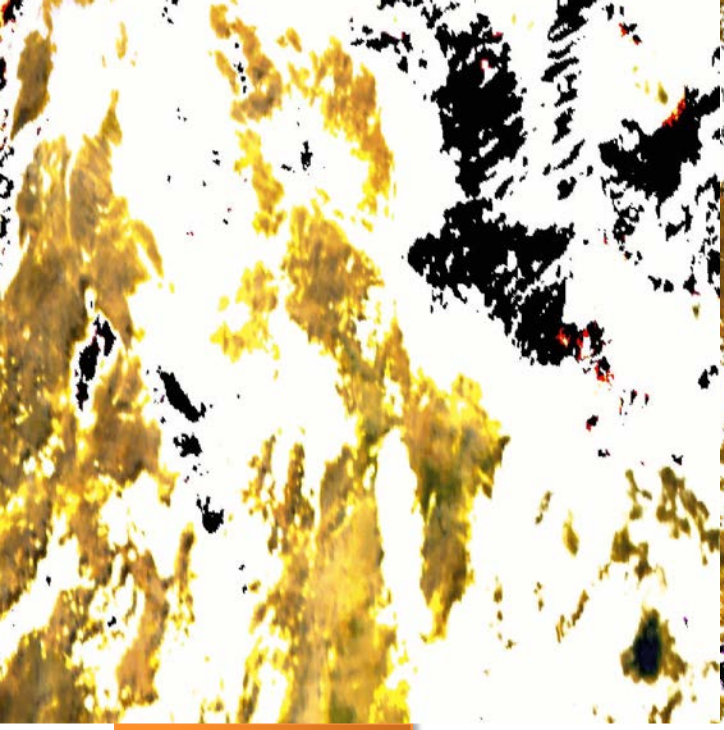
1 year's result in N CHN

TOA

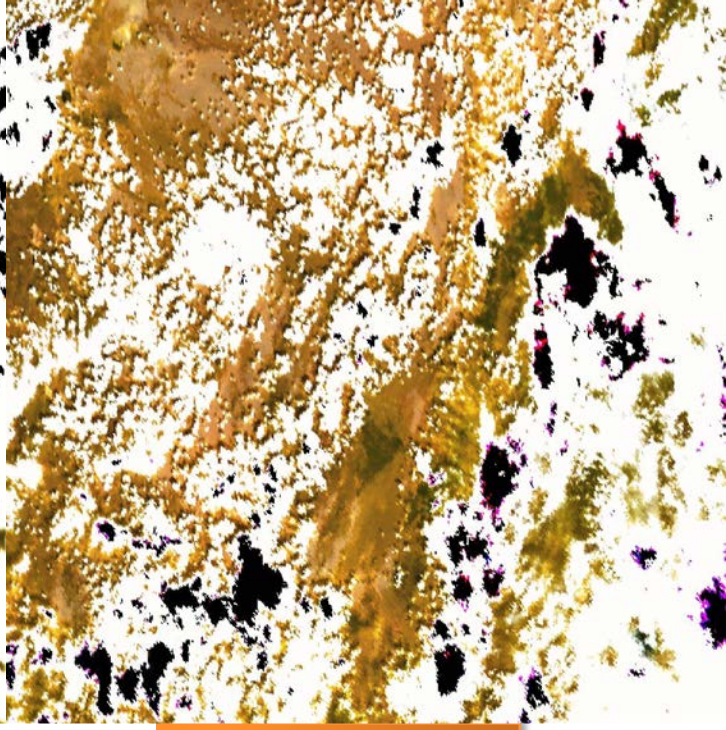


BOA

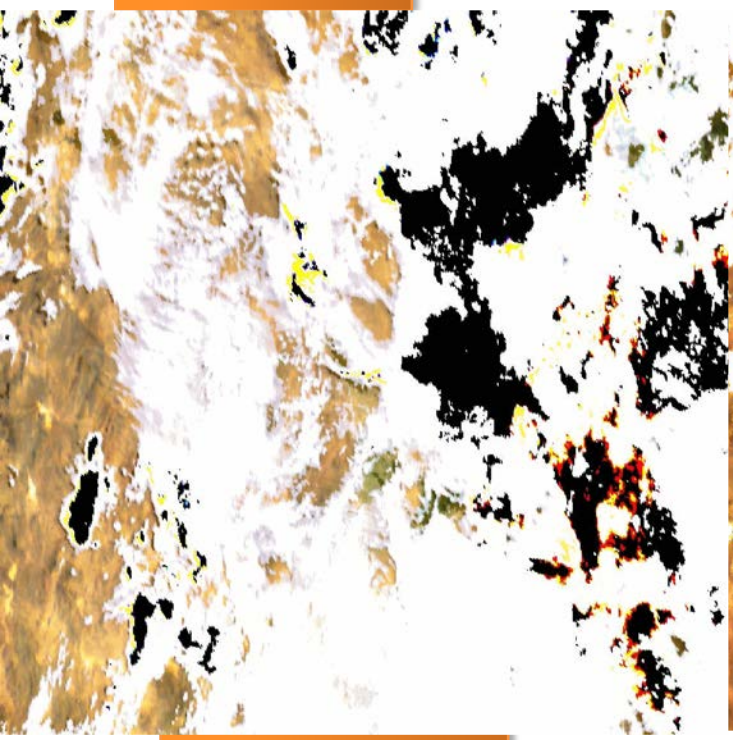




MYD



FY3B/MERSI

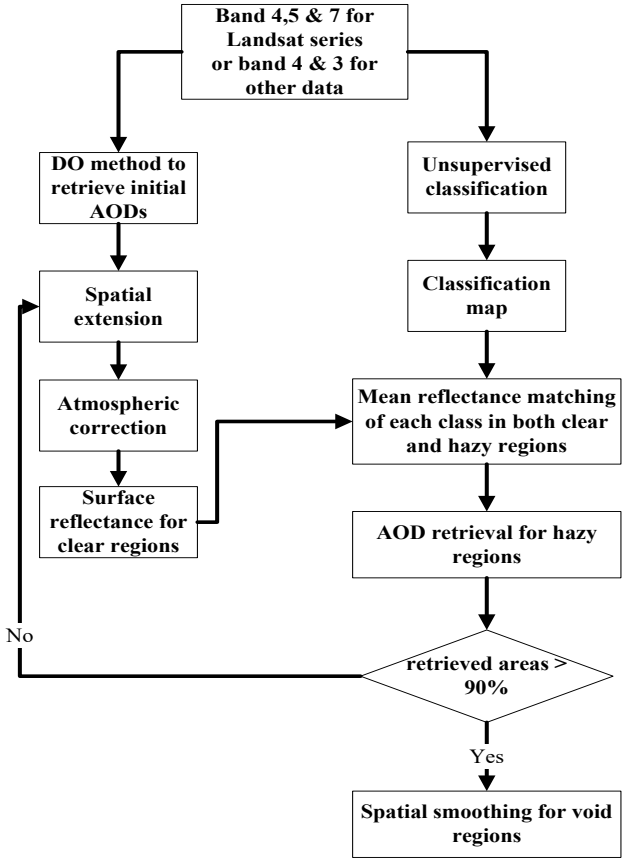


MOD

FY3A/MERSI

Surface Reflectance

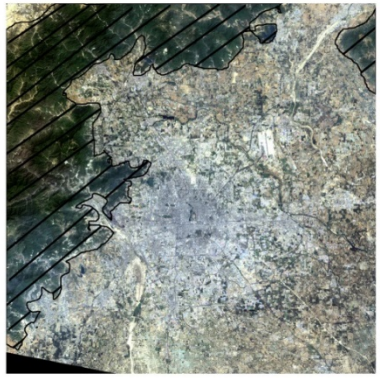
Atmospheric correction-MH



✓Based on signature separation: high frequency land and low frequency atmosphere

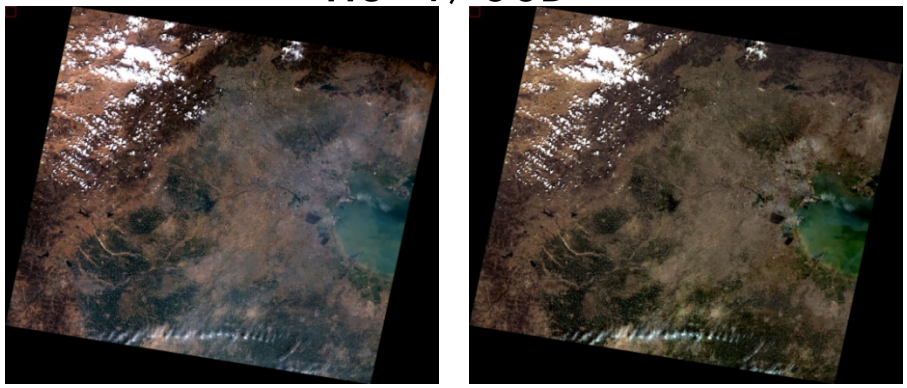
✓No other information needed

✓Automated

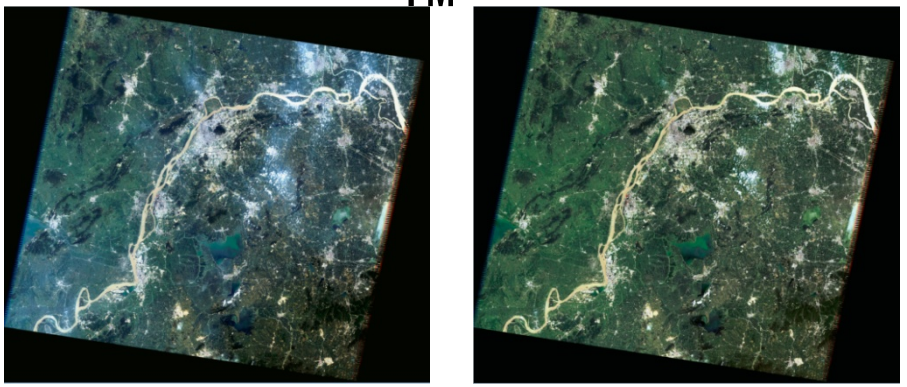


Atmospheric correction for major moderate to high resolution data

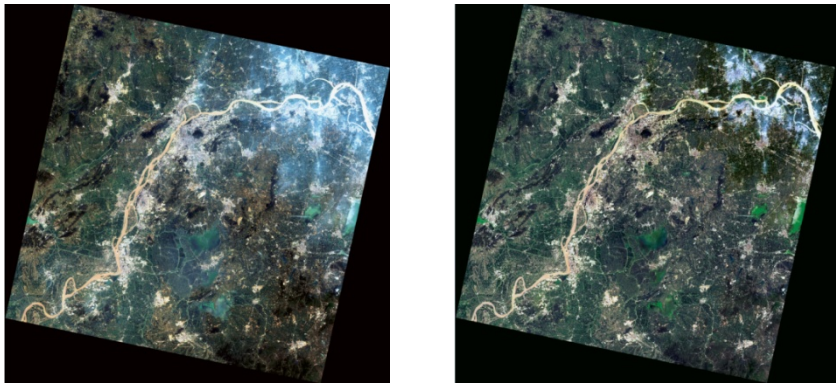
HJ-1/CCD



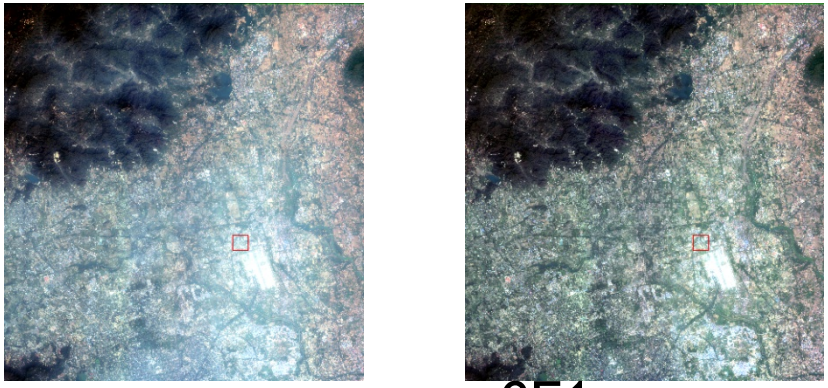
TM



TM8

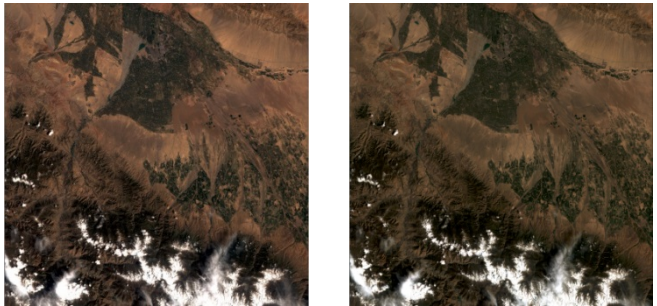


ZY3

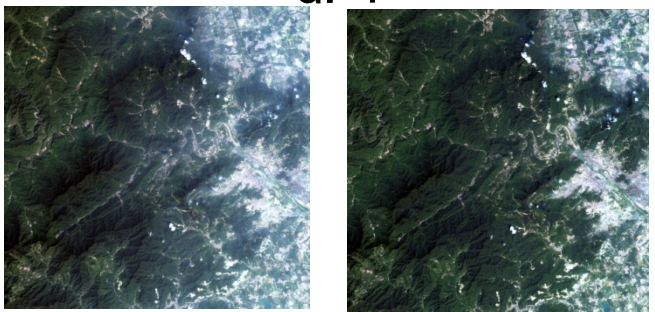


GEOEYE

THEOS



GF1

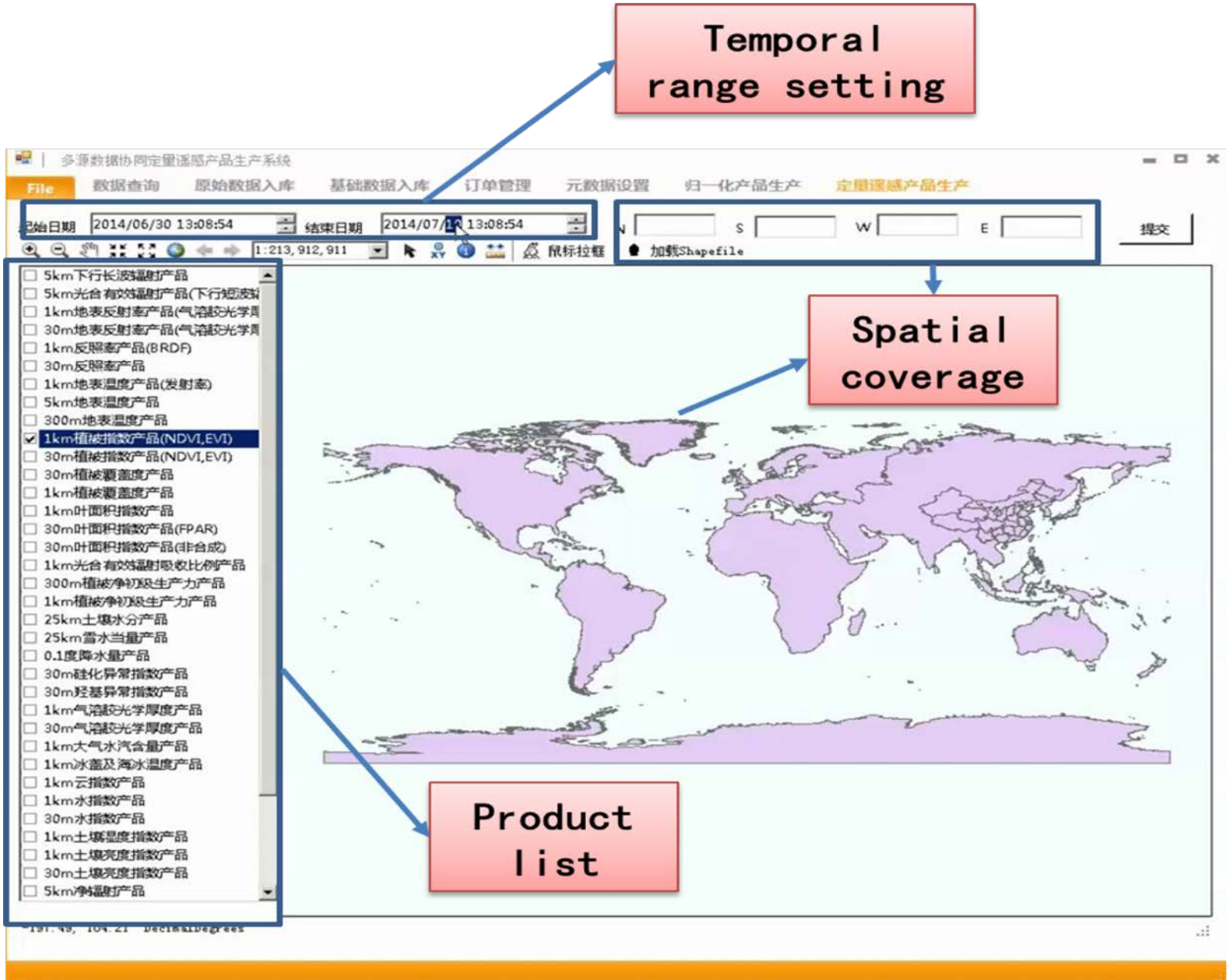


5. MuSyQ Products

Production System

- **Multi-source data Synergized Quantitative remote sensing production system**
- **MuSyQ** pronounces **as Music**

Software and UI



Products

5km resolution——5

- 5km land surface temperature, MuSQ.LST.5km
- 5km DSR, MuSQ.DSR.5km
- 5km DLR, MuSQ.DLR.5km
- 5km PAR, MuSQ.PAR.5km
- 5km Net radiation, MuSQ.NSR.5km

300m ——1，30m——2

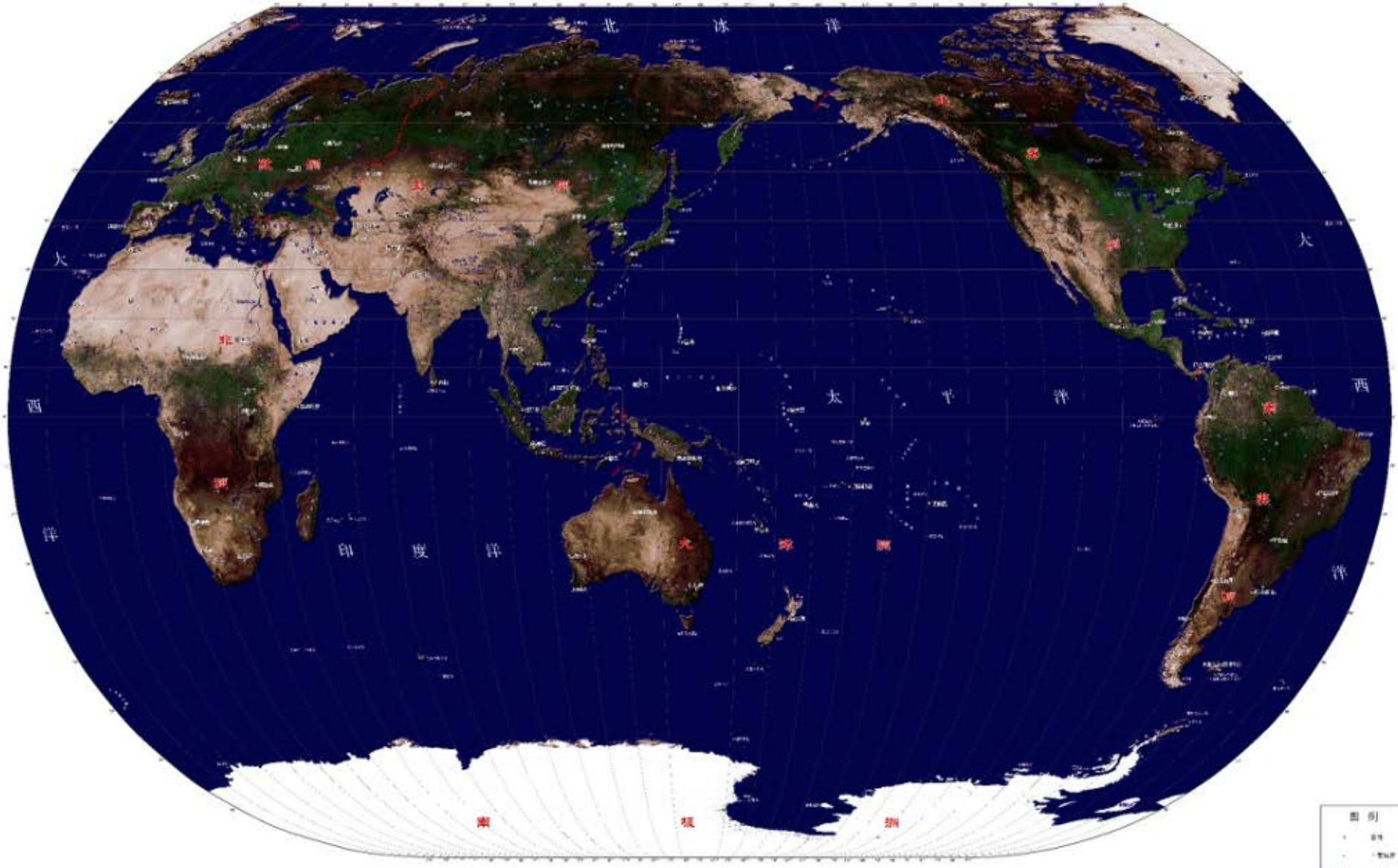
- 300m surface temperature，MuSQ.LST.300m
- 30m BRDF/albedo，MuSQ.LSA.30m
- 30m AOD， MuSQ.AOD.30m

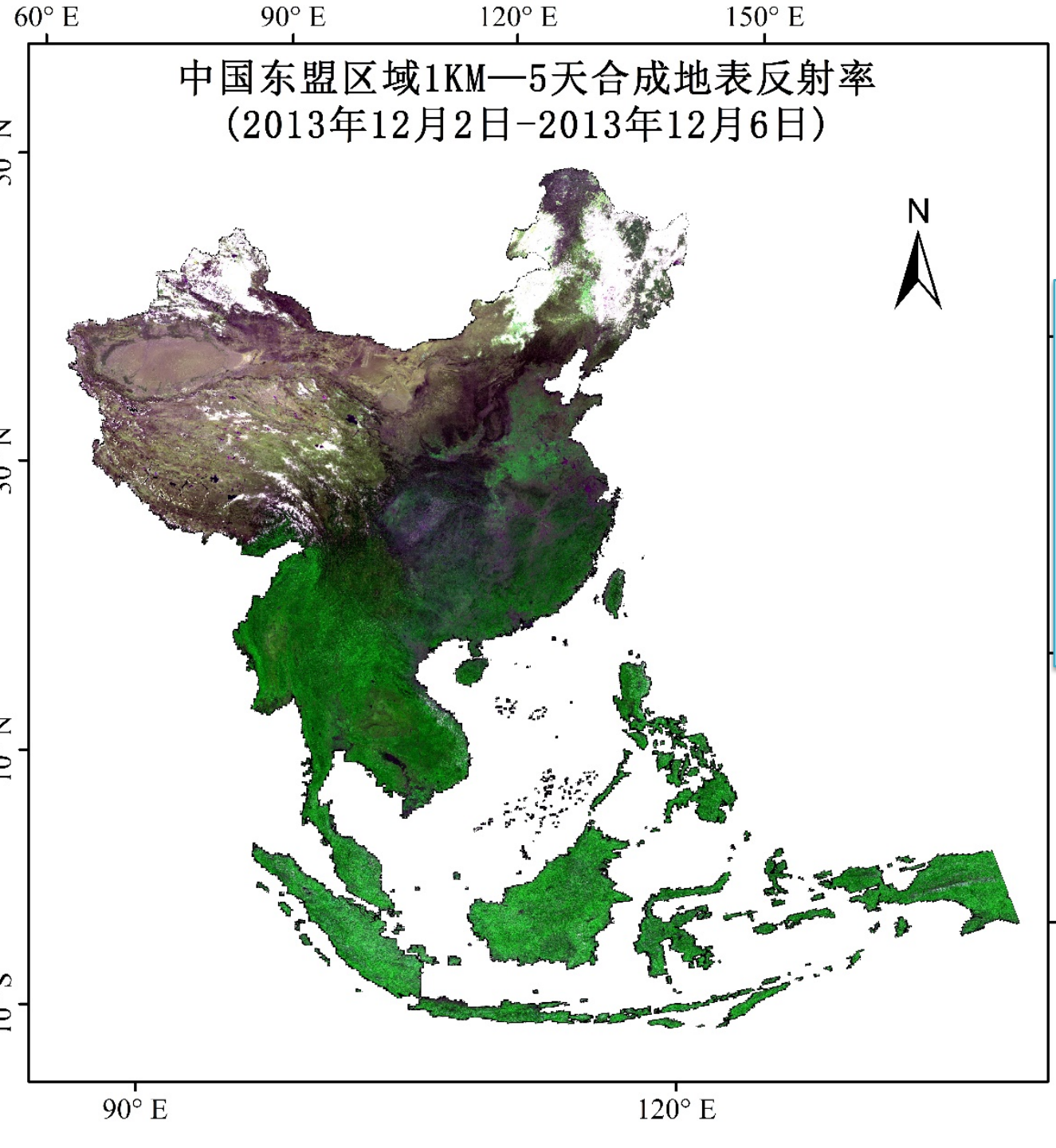
1km resolution——8

- 1km emissivity，MuSQ.LSE.1km
- 1km albedo，MuSQ.LSA.1km
- 1km surface temperature，MuSQ.LST.1km
- 1km DSR， MuSQ.DSR.1km
- 1km DLR， MuSQ.DLR.1km
- 1km PAR， MuSQ.PAR.1km
- 1km AOD, MuSQ.AOD.1km
- 1km net radiation，MuSQ.NSR.1km

MuSyQ Surface Reflectance Products

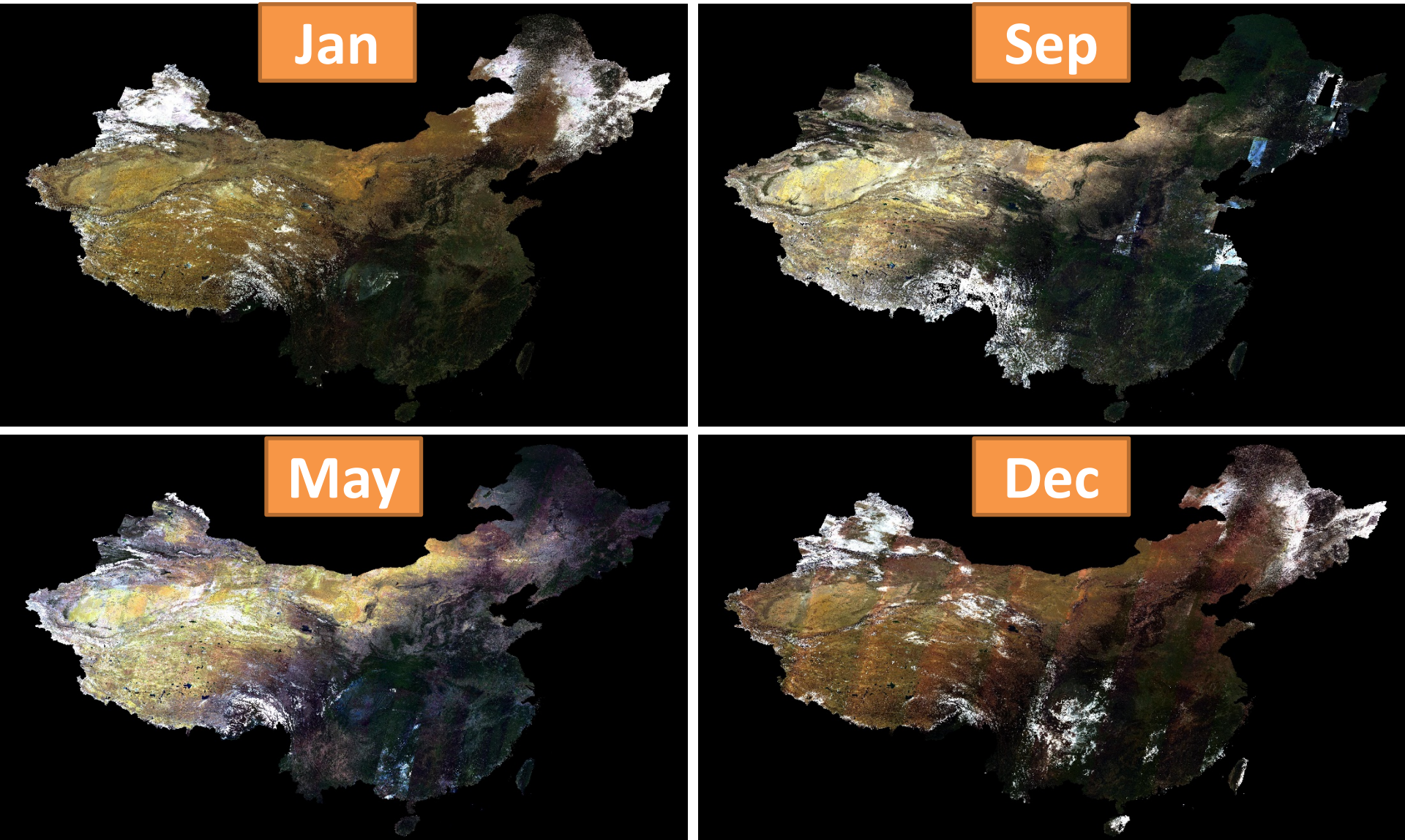
1 km/5-day composite surface reflectance product day 188-192, 2012

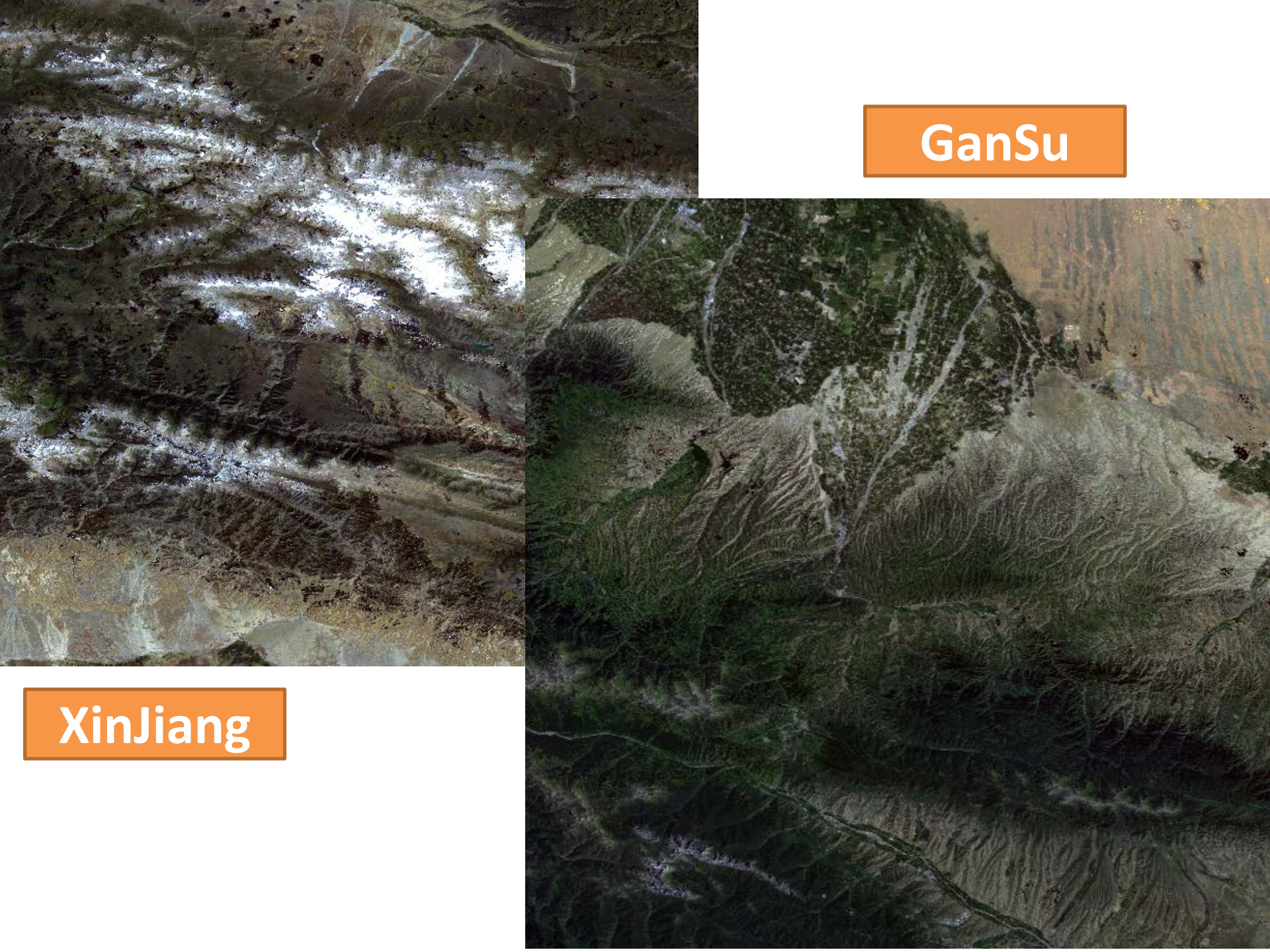


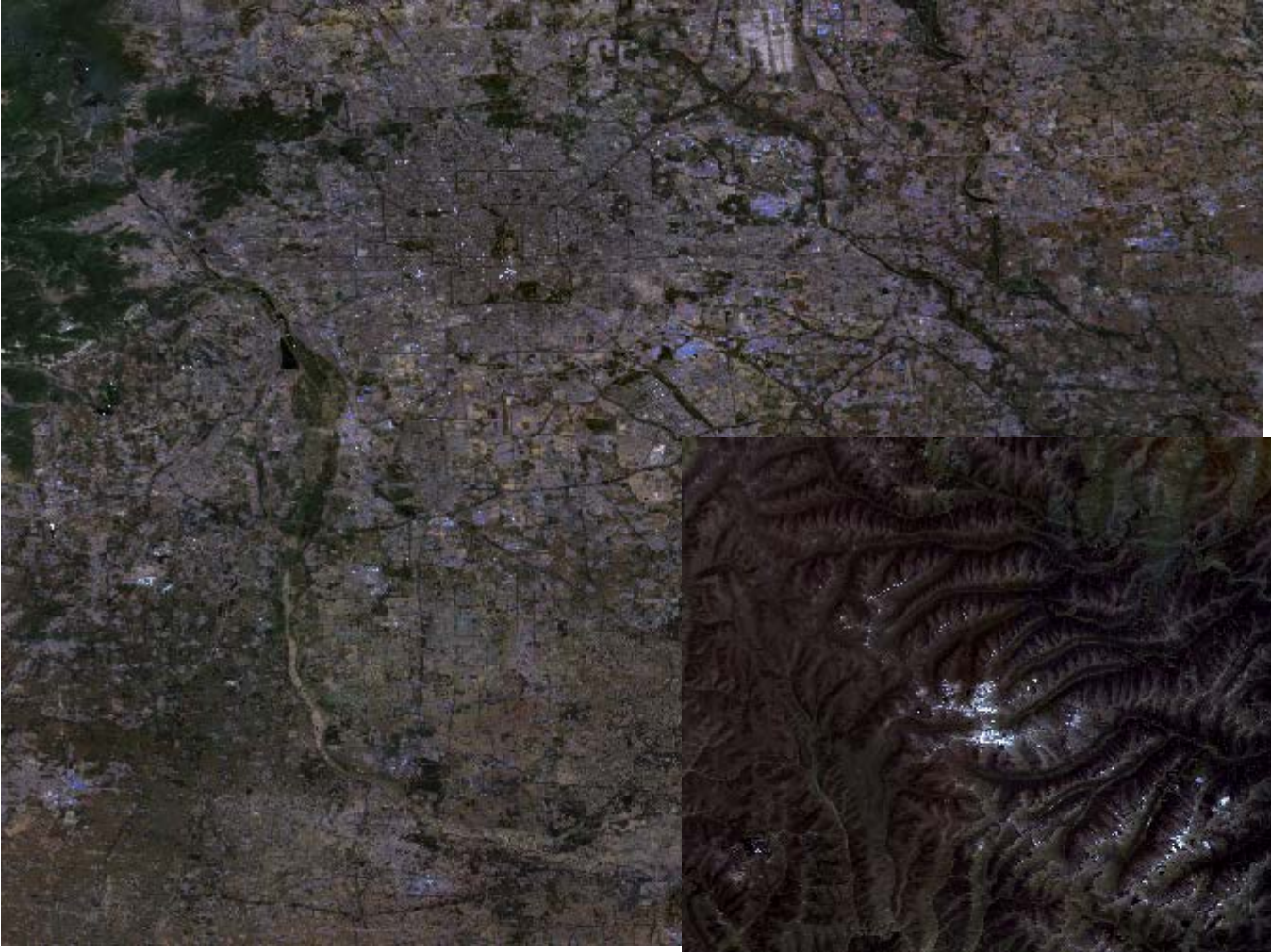


ZHONG et al.2015. Global Change Research Data Publishing & Repository, DOI:10.3974/geodb.2015.02.02.V1, http://www.geodoi.ac.cn/WebEn/doi.aspx?DOI=10.3974/geodb.2015.02.02.V1

MuSyQ 30m monthly mosaics --surface reflectance



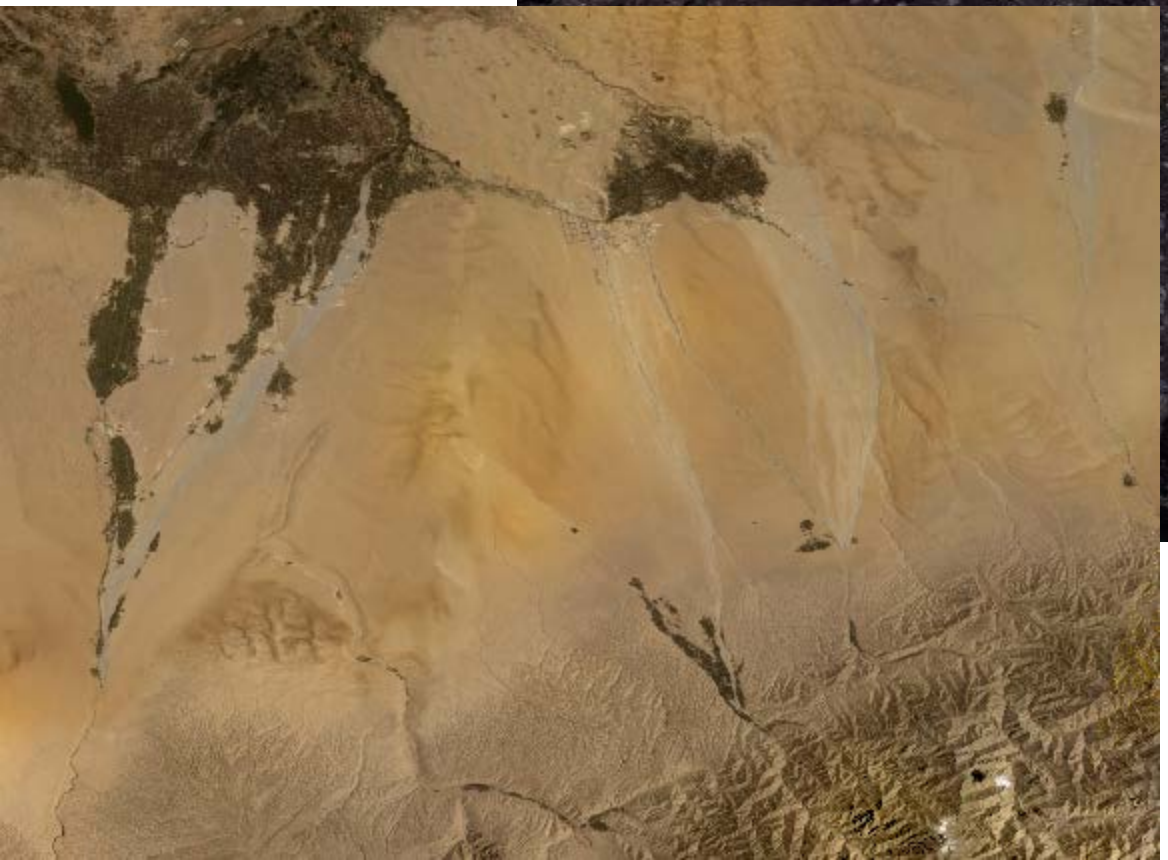

GanSu
XinJiang



Beijing

Sichuan

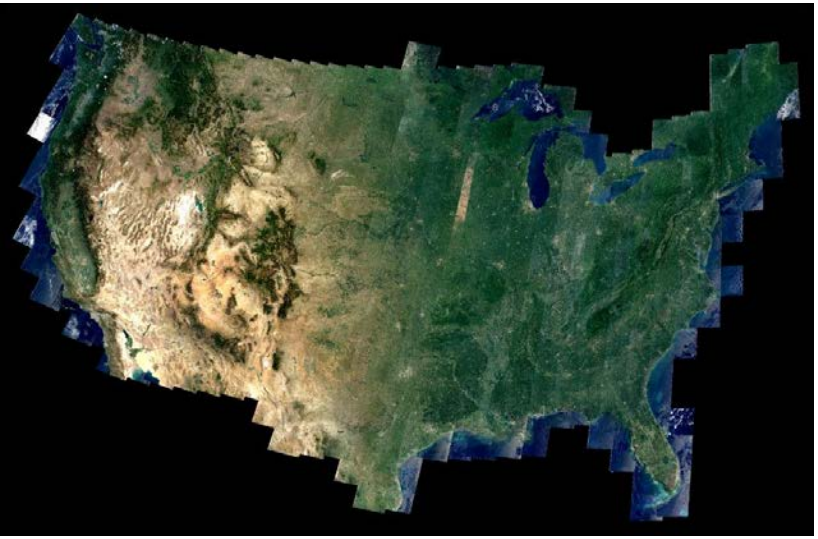
Taklimakan

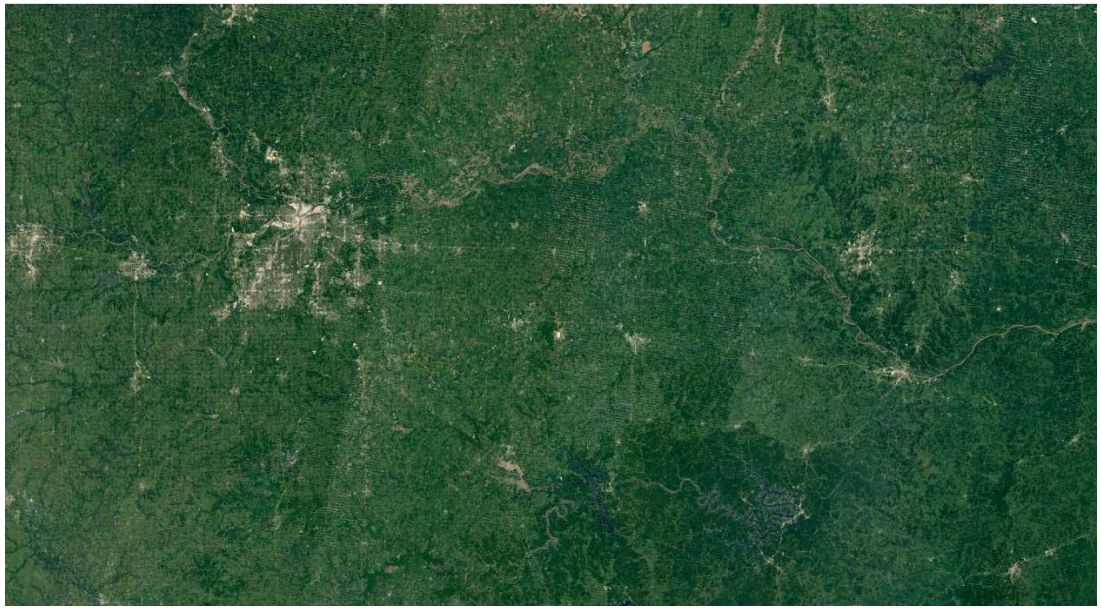


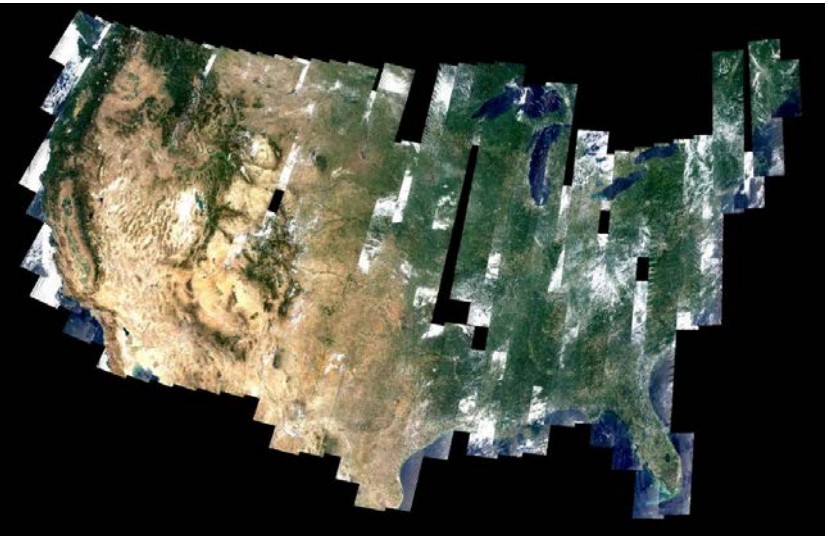
Jilin

Temporal variation

WELD 30m mosaics
-- apparent reflectance

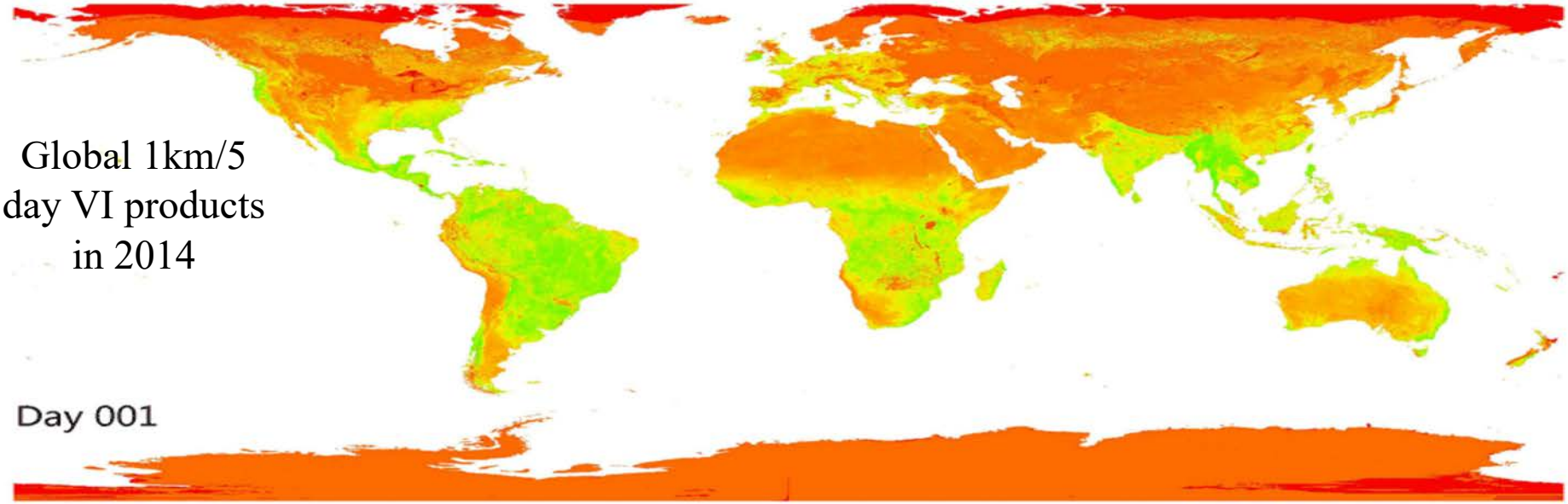






MuSyQ Vegetation Products

- Global 1km/5 day VI products derived from MODIS, FY3/MERSI multi-source datasets in 2014

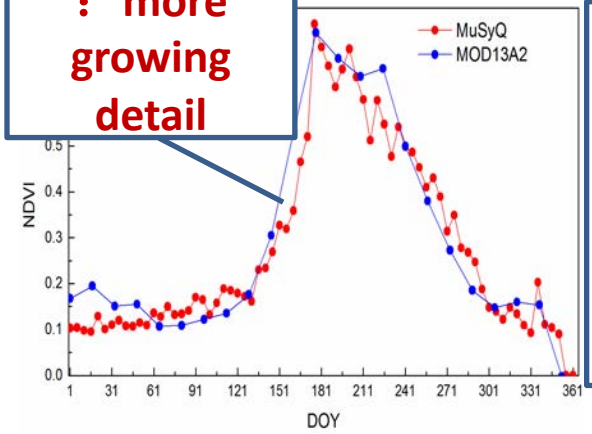


Global 1km/5 day VI products in 2014

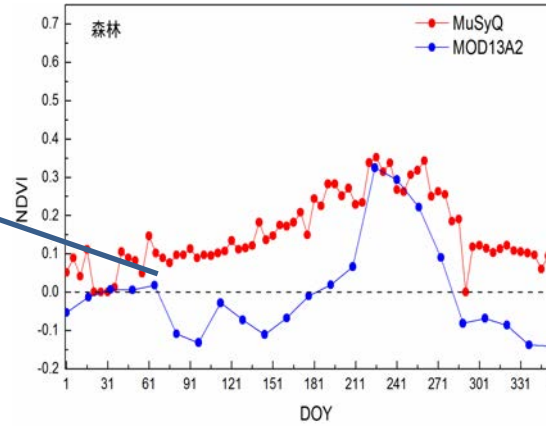
✓ Promote temporal resolution significantly: From 16 days to 5 days

Advantage1 : more growing detail

Comparison between MODIS and MuSyQ NDVI time serie

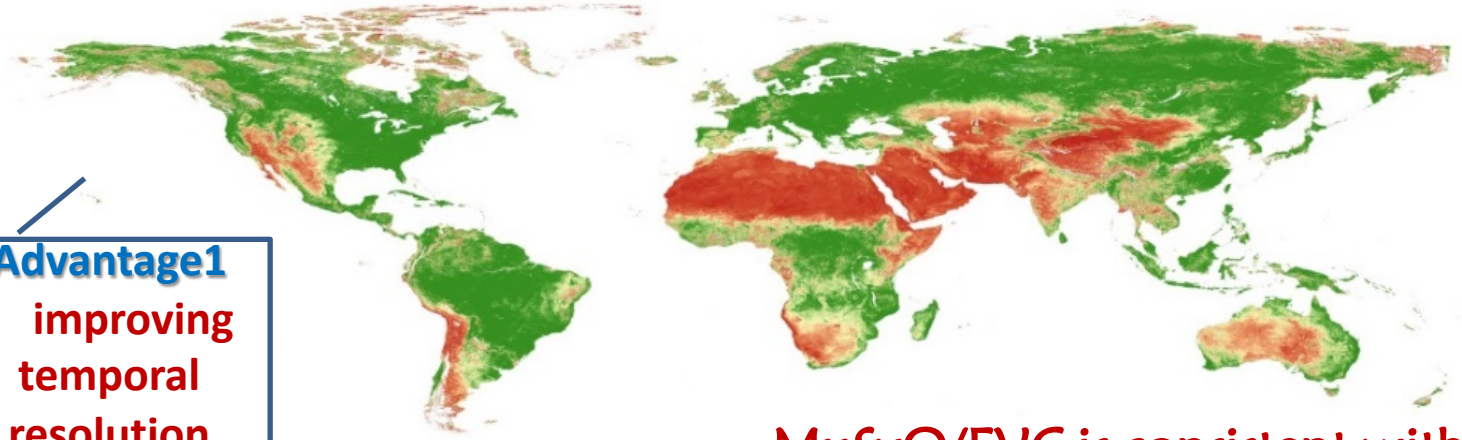


Advantage2 : multi-source observation and better quality controlling

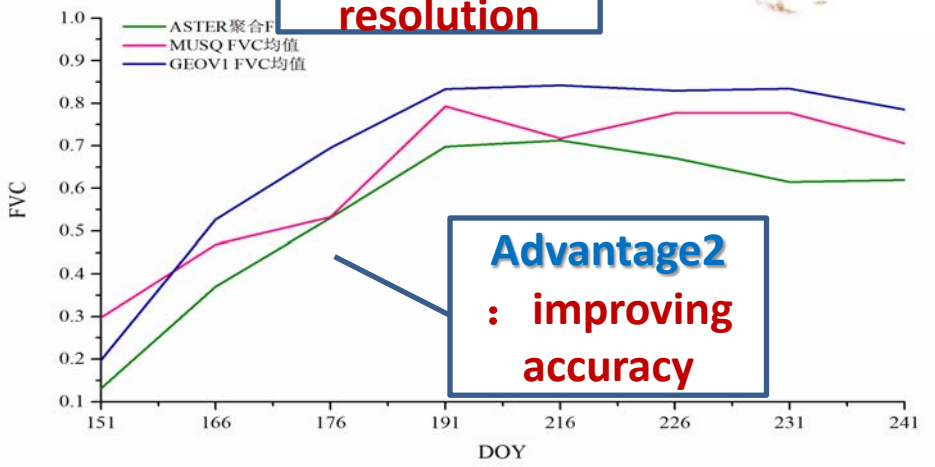


- Generating global vegetation fraction product(1km/5days) in 2014 based on global climate regionalization map, land use map and MuSyQ/NDVI product

Global vegetation fraction product



Advantage1 : improving temporal resolution



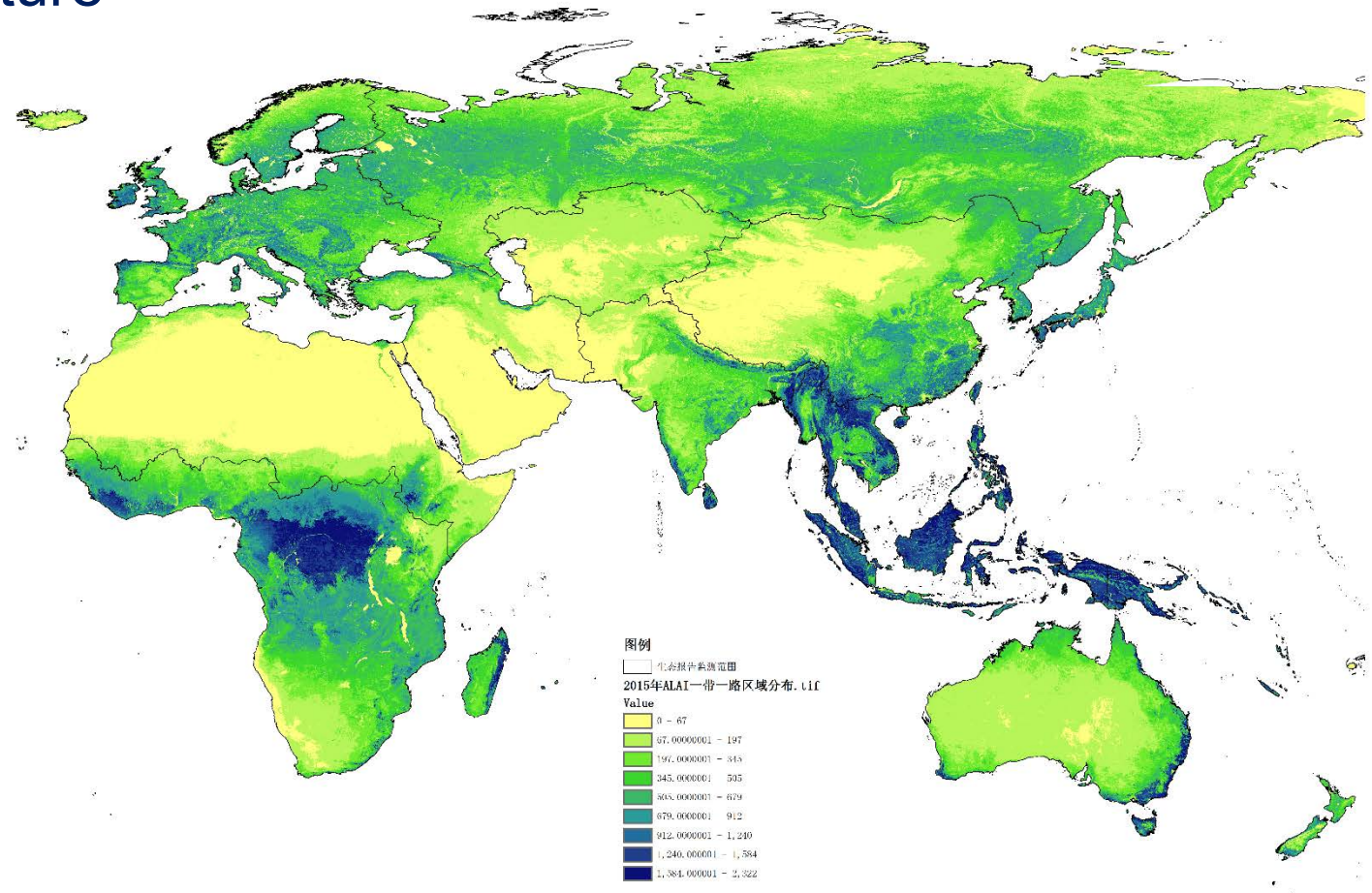
Advantage2 : improving accuracy

MuSyQ/FVC is consistent with reference ASTER in trend, and it's value is higher than ASTER generally, accuracy is better than GEOV1.

Fig. multitemporal curve of MuSyQ/FVC、GEOV1/FVC、ASTER reference value in Heihe Basin

Xihan Mu*, Shuai Huang, Huazhong Ren, Guangjian. Yan, Wanjuan Song, Gaiyan Ruan, 2015, Validating GEOV1 Fractional Vegetation Cover Derived From Coarse-resolution Remote Sensing Images Over Croplands, IEEE JSTAR, 8(2): 439-446.

- Product: 1km/ 5day LAI product over “One Belt and One Road” area generated based on algorithm considering water mixture



MuSyQ Radiation Products

	product	resolution		enhancements
1	AOD	1km	product	10km to 1km;
		30m	algorithm	
2	DSR	5km	product	1° to 5km
		1km	algorithm	
3	DLR	5km	product	1° to 5km
		1km	product	
4	PAR	5km	product	
		1km	algorithm	
5	albedo	1km	product	
		30m	product	8 days 5 days
6	LST	1km	product	
		5km	product	
		300m	product	
7	Canopy temperature	300m	technique	
8	emissivity	1km	product	
9	Net radiation	5km	product	

enhancements

1. a simple model for BRDF/albedo retrieve using multi-source remote sensing data

information evaluation method for multi-source data

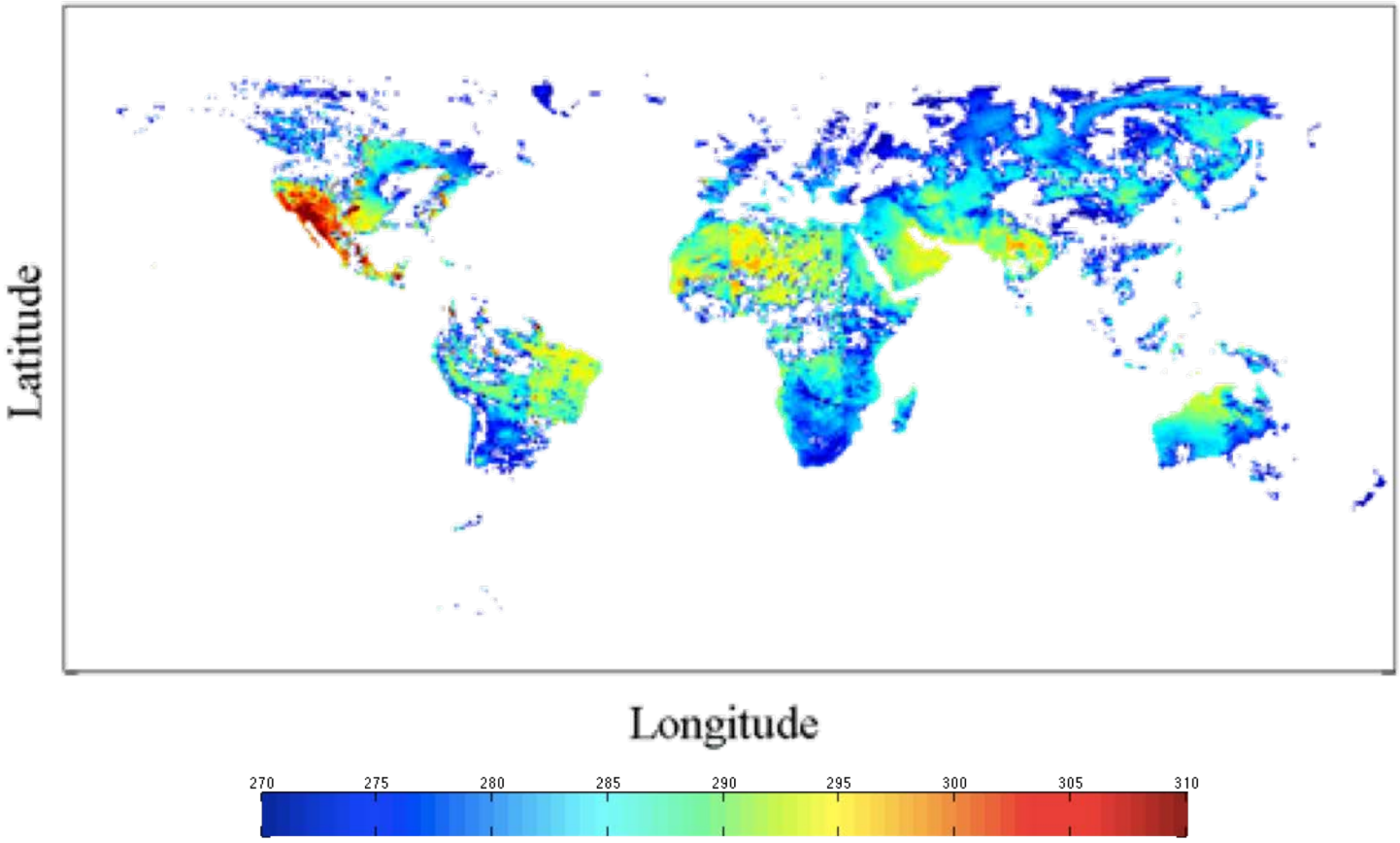
2. Hourly global LST product

optimizing split window algorithms, using geostationary satellite data to increase temporal resolution

3. Global coverage high spatio-temoral resolution DSR product

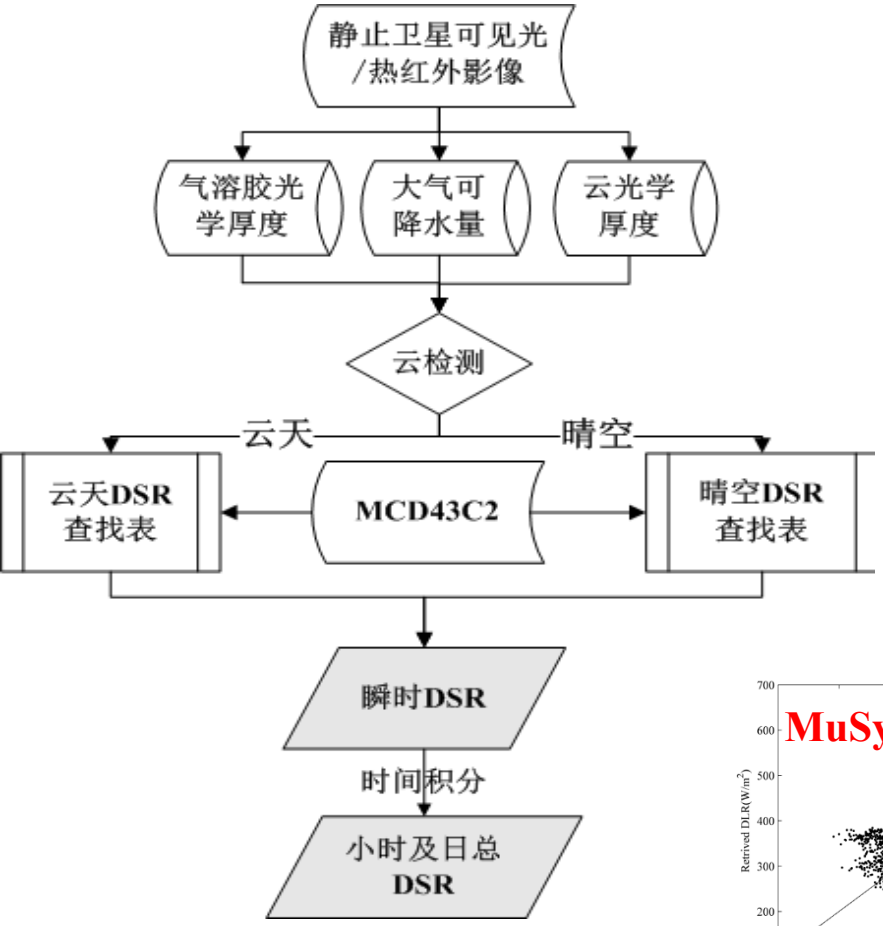
2. 5 km hourly global LST product

- Global geostationary satellites networking: FY2E/MSG/GOES-13/GOES-15



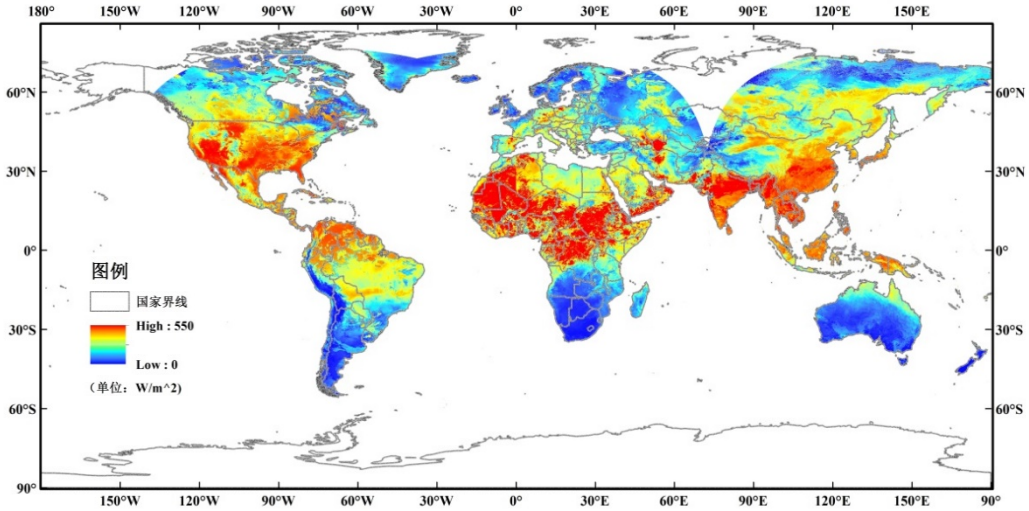
June 1, 2016

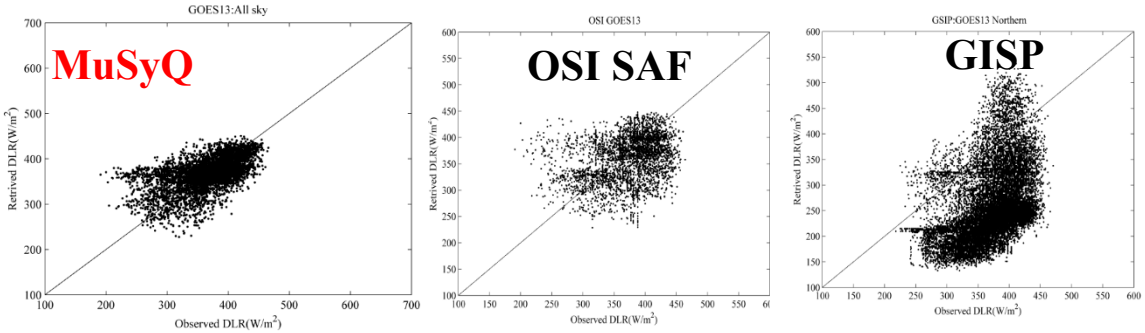
DSW product from MuSyQ



Algorithm

15min ~ 1h，5km



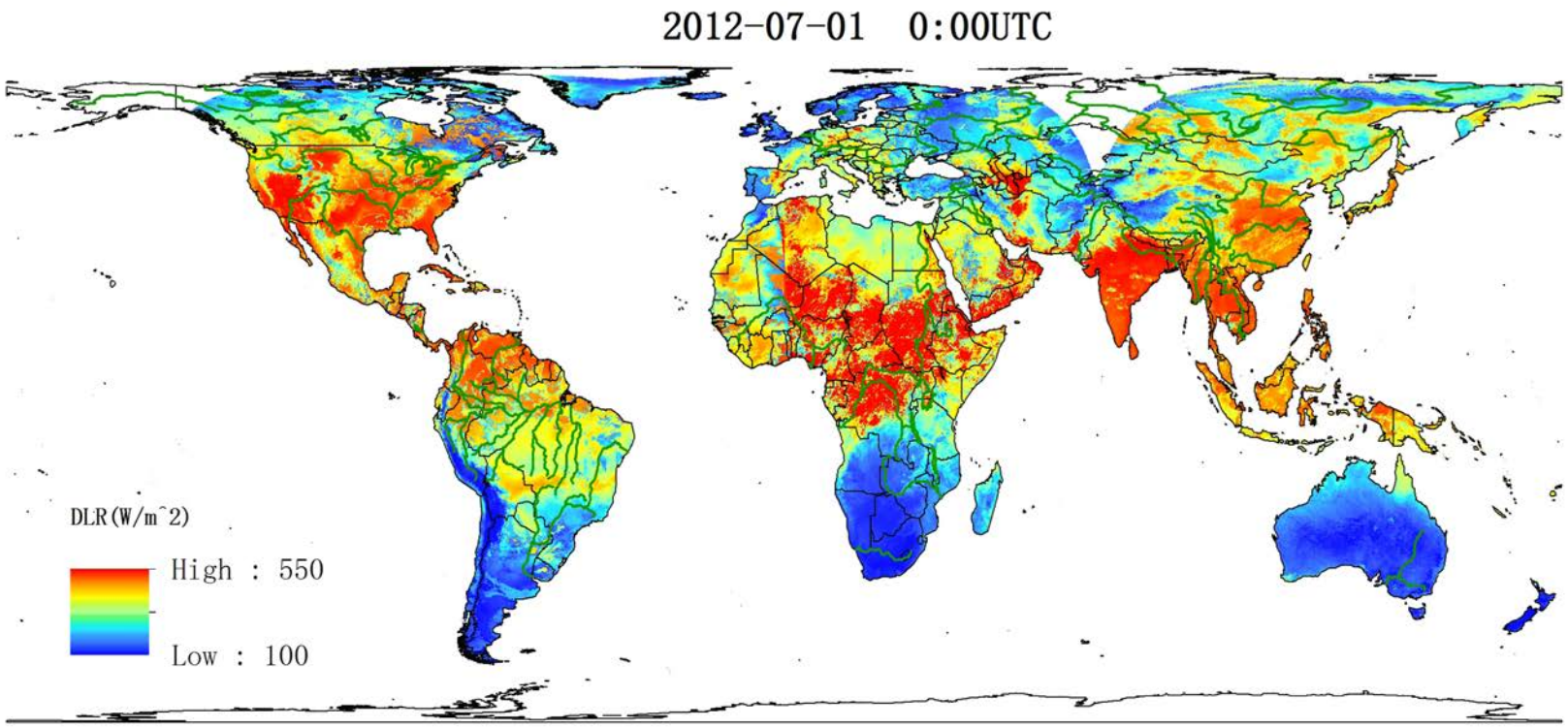


DLR at American areas

Li Li, **Xiaozhou Xin**, Hailong Zhang, Jiangfeng Yu, Qinhuo Liu. **Remote Sensing of Environment**, 2015, 165, 14-26（**SCI，IF= 6.393**）

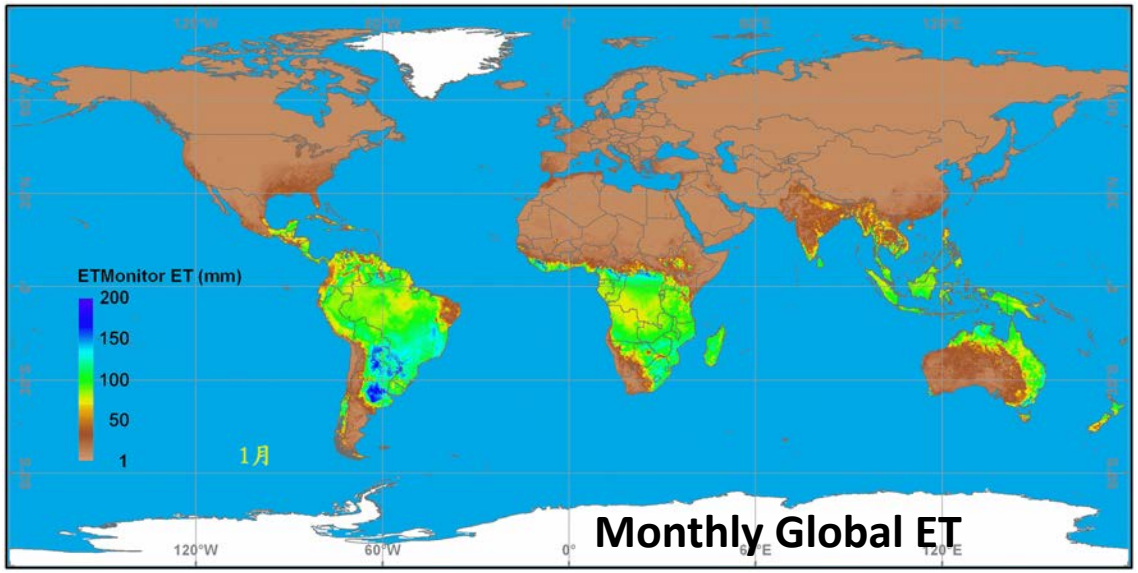
DLW product from MuSyQ

GOES13, MTSAT2, MSG2

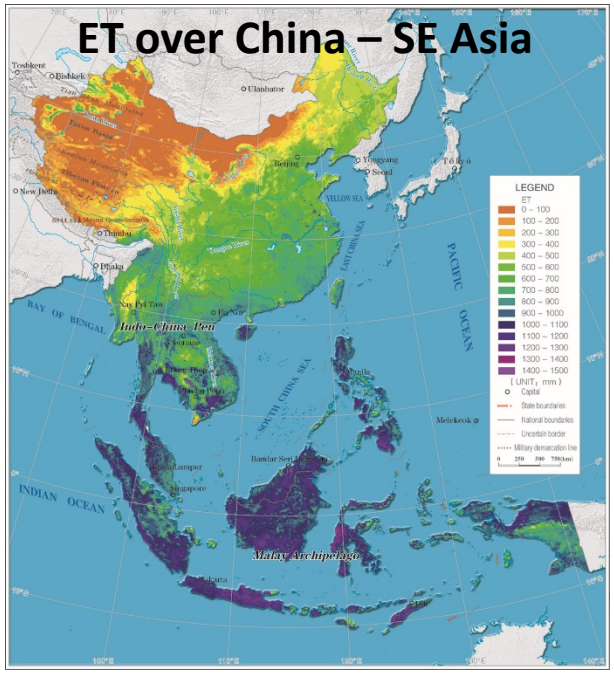


MuSyQ ET Products

Evapotranspiration Products

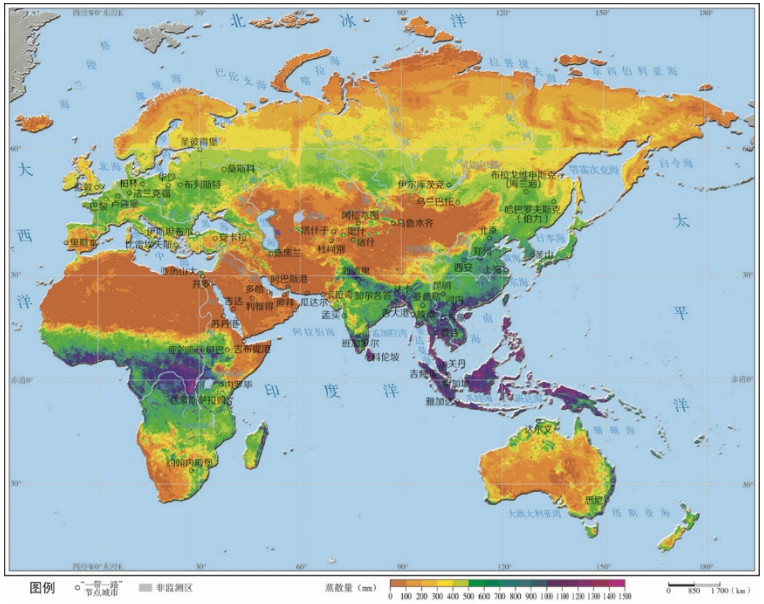


Monthly Global ET



ET over China – SE Asia

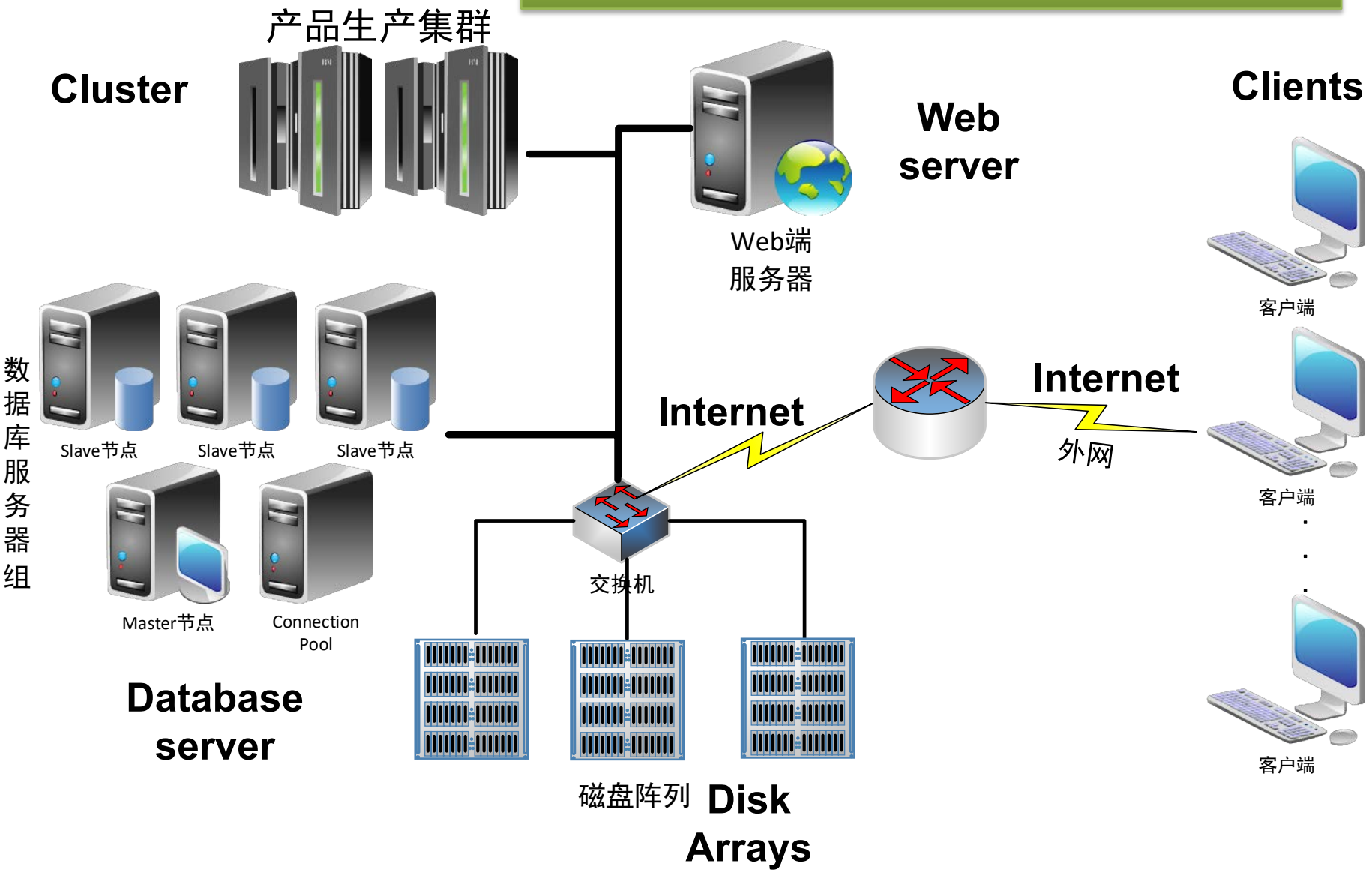
ET over “Belt & Road” Region



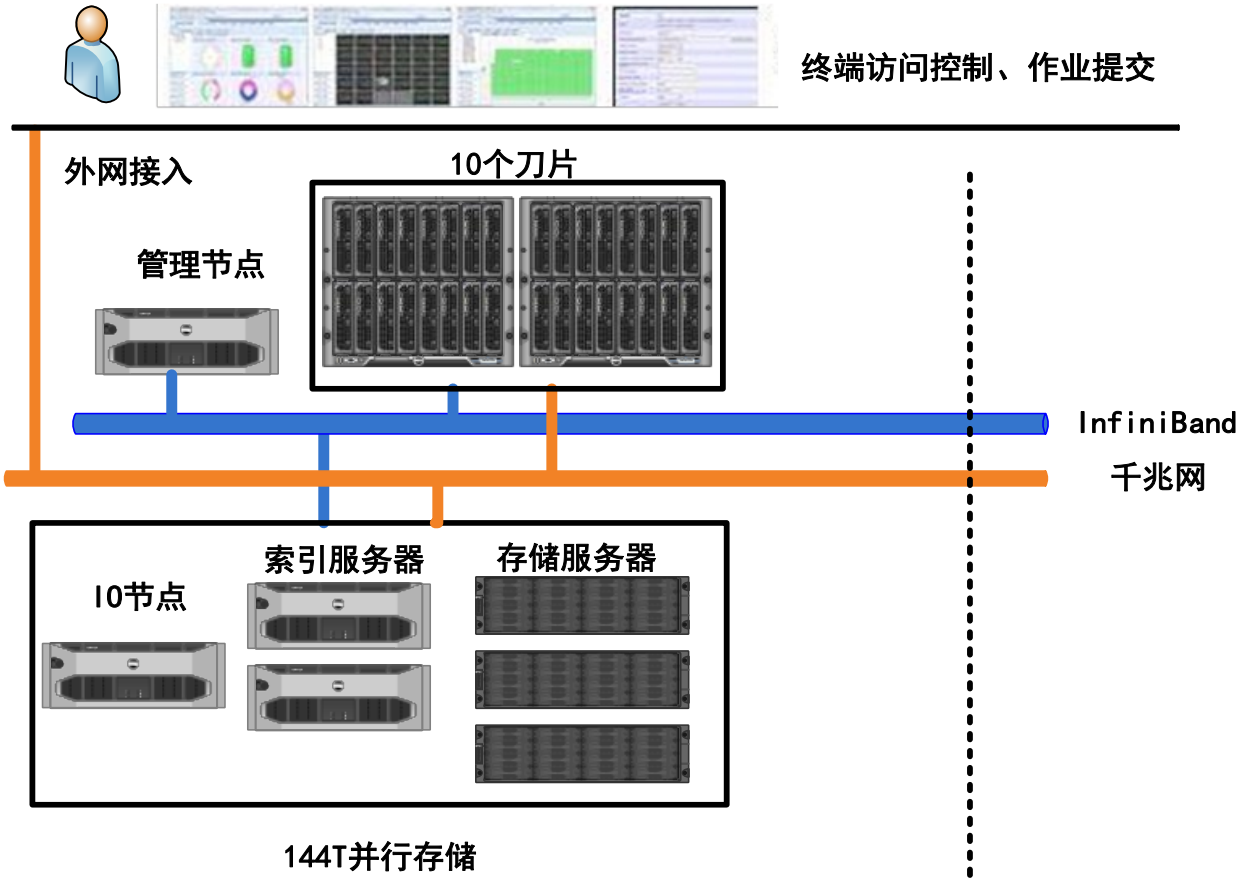
6. Hardware

Cyber infrastructure for global production

Hardware Architecture



Super computing configuration



Center 1

- 16 nodes： 12 CPUs/node，24GB memo/node
- Computing Storage 56TB
- Data storage 182TB

Center 2

- 20 nodes： 24 CPUs/node， 64GB Memo/node，Computing storage 31TB/node

Example: Data acquired and processed

China and southeast Asia Moderate to low resolution data(1.5 year)			
Data type	**Amount (TB)**	**Number**	**Amount after processing (TB)**
FY3	**5.4T**	**21266**	**3.5TB**
MODIS	**2.69T**	**18725**	**5.1TB**
MTSAT	**2.65T**	**23338**	**1TB**

- **Based on the hardware architecture, these data can be fully processed in just 1 day**
- **Globally**
- **Envisat/MERIS, NOAA/MeTop-AVHRR, MSG2, GOES, FY2E**
- **Trying to lower the interval to 3 days**

7. Conclusions

Conclusions

- The technologies for normalizing multi-source remotely sensed data are developed
- The hardware for automatically processing is ready
- The capability for global production is equipped
- The ability for observing the earth in 5 even 3 days at 1km scale is ready to go
- The ability for observing the earth monthly at 30m scale is upcoming

Thank you for your attention

and

Questions!